TECHNICAL BULLETIN No. 139 DECEMBER, 1929

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Branch of Research, Forest Service

UNITED STATES DEPARTMENT OF AGRICULTURE, WASHINGTON, D. C.

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INTRODUCTION

The purpose of this bulletin is to furnish detailed information on the properties and characteristics of the wood of western hemlock, known commercially as West Coast hemlock, which will assist consumers in determining the suitability of this species of wood for specific uses.

The most effective way of describing the properties of a little-known wood is to compare them with the properties of well-known woods. The comparisons of properties of wood made in this bulletin are based primarily on the properties of clear wood. In the lumber trade, however, comparisons of specific properties of species of wood are usually based on the lumber as sold or delivered and are influenced by the size and character of defects, dressed sizes, degree of seasoning, and marketing practices. Thus, the clear wood of one species may be stronger than that of another in a particular property, but when the size and character of the defects in a commercial grade are considered, the advantage may disappear or be reversed. Again, a comparison of strength based on clear wood will not hold for similar items of lumber of different species of wood when the actual sizes of the items differ. Thus, in a comparison of the strength of pieces

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

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nominally 2 by 4 inches, which in one species of wood are 1⅝ by 3⅝ inches and in another 1¾ by 3⅝ inches, one must consider the difference in size as well as the difference in the inherent properties of the clear wood of the species. The advantage of inherently low shrinkage or of high nail-holding power as shown in this bulletin for certain species of wood may be more than lost through the method of marketing or the use of the species before it is sufficiently dry.

The relative usefulness of western hemlock, or any other lumber, depends upon the characteristics of the stock in its entirety as well as upon the properties of the clear wood, and it depends more upon a combination of properties than upon any single property. For example, nail-holding power, strength, and weight of the clear wood of a species may indicate that it is an excellent wood for boxes for bulk commodities, but the lumber may be unsuited for such use because of a characteristic of the knots to loosen and fall out.

This bulletin, therefore, attempts to show how the information given on the different properties and characteristics may be combined and applied in determining the suitability of western hemlock for certain uses. The discussion of the uses of western hemlock are and must be considered largely illustrative, because complete information is lacking on the exact requirements of even the typical use conditions discussed. The conditions that apply to any specific case are, of course, recognizable to the user, and he must judge where and how his special conditions depart from the general condition assumed in this bulletin.

For most uses a number of species of wood will give equal satisfaction, providing the design of the structure and the preparation of the lumber are varied in accordance with its use requirements; for design is a great equalizer of species. The selection of a species for any use, however, requires a consideration of the cost of the different species as well as the cost of constructing the different designs that are necessary to obtain equally satisfactory results from species with different properties.

CHARACTER AND RANGE OF THE WESTERN HEMLOCK FOREST

Western hemlock grows along the Pacific coast from Prince William Sound in Alaska to northern California and as far inland as northern Idaho and northwestern Montana. (Fig. 1.) In the United States on the west slope of the Cascade Range and the east slope of the Coast Range and Olympic Mountains, western hemlock forms from 5 to 30 per cent of the stand in which Douglas fir is the principal species. On the western slopes of the Olympic Mountains and the Coast Range, western hemlock at some places constitutes more than one-half of the forest stand which includes Sitka spruce, western red cedar, Douglas fir, and true firs. It has its best growth and development in pure stands or in mixture with other species in even-aged stands on the lower slopes west of the Cascade Range where the climate is cool and moist. At higher elevations, with more marked extremes in climate, it is not abundant, nor does it attain large size.

Under the best growth conditions the trees attain a diameter of 3 to 4 feet and a height of 175 to 225 feet. Larger trees are found but those over 5 feet in diameter are very rare. The cylindrical

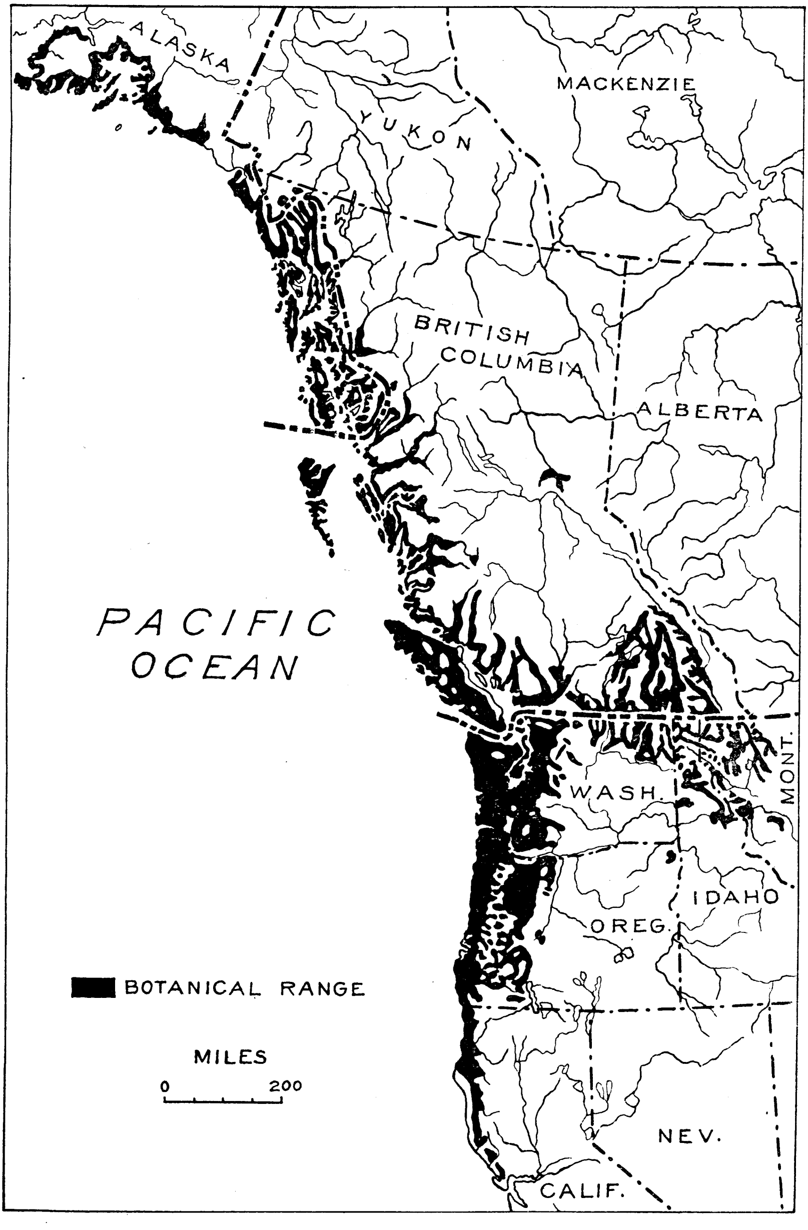


FIGURE 1.—Western hemlock (*Tsuga heterophylla*) botanical range

boles are long and slender and support short and narrow crowns. (Pl. 1.) The understory trees grow slowly, and are relatively short, heavy limbed, and of comparatively poor quality. Decay in living western hemlock trees is generally due to Indian-paint fungus or brown rot, which is the heart rot so prevalent in overmature or suppressed forest stands (*31*).[2] The trees are also subject to attack by the hemlock maggot, which causes the characteristic "dark streak" or "black burl" in the wood.

CUT AND SUPPLY

The species, which is a prolific seed bearer, reproduces vigorously and grows well under a wide range of conditions. If properly taken

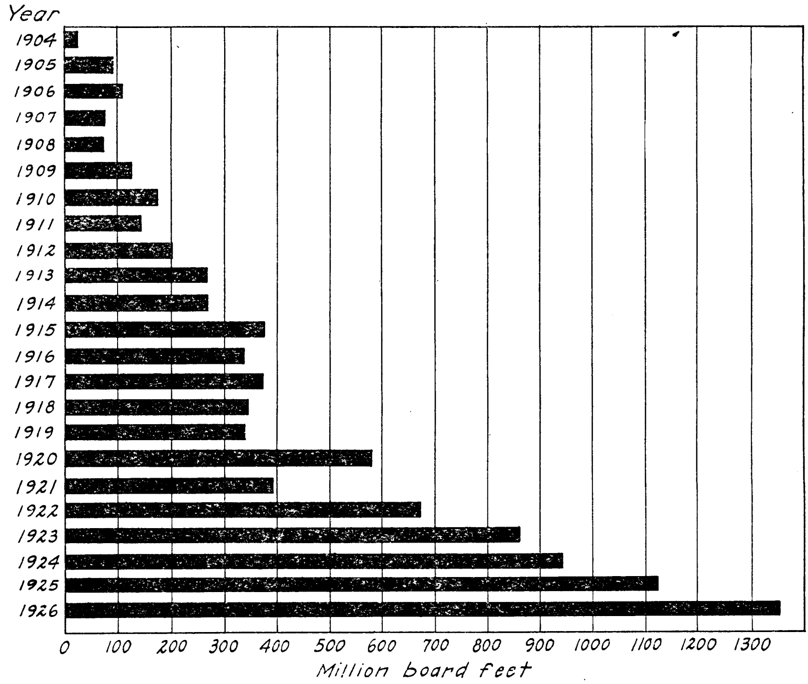


FIGURE 2.—Production of western hemlock lumber in the United States, 1904 to 1926

advantage of, these characteristics, together with the fact that the existing stands are large, will go far toward assuring a sustained supply of western hemlock wood.

A rapidly increasing proportion of the lumber manufactured in the United States is cut from western hemlock. In 1908 the species ranked twenty-fifth in lumber production, furnishing only 0.2 per cent of the total output. In 1920, as shown by Figure 2, the cut of western hemlock began to increase rapidly. In 1926 only southern yellow pine, Douglas fir, western yellow pine, and oak were cut in larger quantities.

The output of western hemlock in the continental United States, exclusive of Alaska, as computed from the Bureau of Census figures

[2] Reference is made by italic numbers in parentheses to "Literature cited," p. 60.

for 1926, was 1,351,152,000 board feet, of which Washington produced 1,156,546,000; Oregon, 190,491,000; Idaho, 2,744,000; and Montana, 1,371,000. In addition, Alaska produced 5,769,000 and British Columbia nearly 200,000,000 board feet.

The supply of western hemlock in the United States and Alaska, as shown by Figure 3, is exceeded only by the supplies of two other species, namely, Douglas fir and western yellow pine.[3] The stand of Douglas fir is estimated to be about two and three-fifths times as large as that of western hemlock; that of western yellow pine is estimated to be about one and one-half times as large; and that of southern yellow pine is estimated to be about equal to that of western hemlock.

The supply of western hemlock in the United States, including Alaska, is estimated (*2*) at about 149 billion board feet, which is probably about 8 per cent of the total saw-timber supply. About 60 billion feet of the stand is located in Washington, 25 billion in Ore-

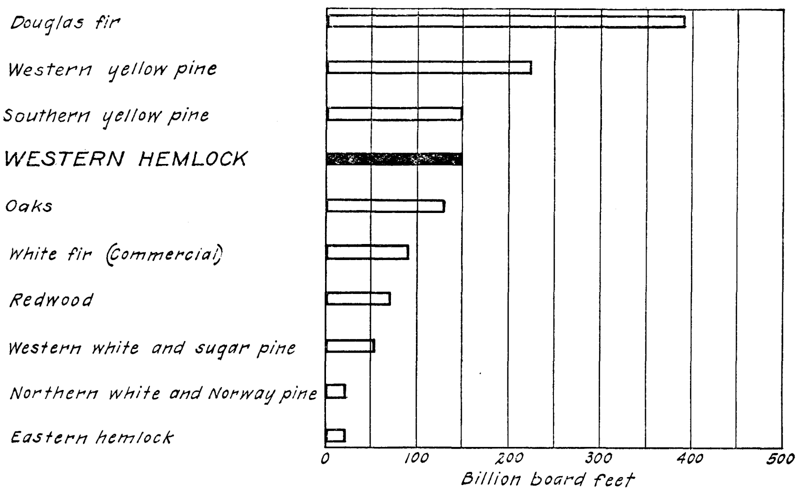


FIGURE 3.—Estimated existing stand of western hemlock and other principal lumber-producing species of wood in the United States and Alaska

gon, and 63 billion in Alaska, and about 1 billion in northwestern Montana and northern Idaho. British Columbia possesses more than 60 billion board feet. The large existing stands of the species are evidence that western hemlock will continue to be of great importance in the output of lumber and pulp wood.

VALUE OF TIMBER

Western hemlock is increasing in the esteem of lumbermen. Stumpage prices in 1927 were about one-third of those of Sitka spruce, western red cedar, and Douglas fir. Twenty years ago the species was considered as having practically no value.

The cost of logging western hemlock is ordinarily high as compared with that of logging other major species of the region. Stands

[3] The standard names employed by the United States Forest Service for lumber and for the trees from which it is cut are used throughout this bulletin (*22*).

from which it is generally cut consist mostly of larger trees of other species. Such conditions demand larger and more powerful machinery than is now economical for logging western hemlock and other comparatively small trees.

A large but decreasing proportion of the output of hemlock lumber is produced in mills built primarily for the economical utilization of other and larger species; the typical modern mill of the region is a large, complex plant composed of many units and equipped to produce lumber in a great variety of forms and grades from relatively large-diameter logs. The introduction of logs of smaller size, which materially change the volume of the many forms and grades, clogs certain parts of the mill, and it becomes necessary to slow down the rest of the mill, which increases the manufacturing cost.

The comparatively low yield of clear stock is also a handicap to the species, possibly its greatest. Under the most favorable conditions of growth it contributes less material suitable for clear lumber than Douglas fir and Sitka spruce; not only is it a smaller tree but its limbs do not prune themselves as early in life. The clear portion of the hemlock logs, moreover, is seldom fully utilized for the better grades of lumber, presumably because of operating and merchandising difficulties. Frequently, all or a large part of the potential clear stock goes into common boards and dimension stock, along with the common material.

These and other factors, which have worked to the disadvantage of western hemlock for lumber, are slowly becoming less formidable. Then, too, at the present time it appears that increasing demands on the species will be made by the paper industry; the opportunity in the Pacific Coast States for a greatly enlarged mechanical and sulphite pulp industry is based largely upon supplies of hemlock, Sitka spruce, and true fir, which are much larger than those in any other forest region of the United States. While the choice logs of western hemlock undoubtedly will always be utilized for lumber, there is no apparent reason why the use of this species of wood for paper pulp should not become increasingly important. The Alaska stands of hemlock will probably find their chief use for pulp because of the abundance of water power.

PROPERTIES OF WESTERN HEMLOCK

GENERAL DESCRIPTION

In general appearance the wood of western hemlock somewhat resembles that of eastern hemlock and white fir. It is light in color with a pinkish to a reddish-brown tinge, and has a rather pronounced silky sheen when dry. It darkens somewhat with age after being cut, but not so much as most other species. The colors of the heartwood and sapwood are very similar, although the sapwood, which is very narrow, is sometimes lighter colored than the heartwood. There is, however, never a marked contrast between the two.

The annual-growth rings are, as a rule, relatively narrow and comparatively uniform in width. They are usually more uniform in width than are those of eastern hemlock or southern yellow pine. Although marked, the light reddish-brown and relatively narrow summer-wood bands do not contrast decidedly with the lighter colored spring wood, nor is the line of demarcation between them sharp within each annual ring. The summer wood is much less conspicuous than in Douglas fir and southern yellow pine, but more so than in eastern spruce and in the white pines.

The wood is moderately light in weight, moderately soft, straight grained, nonresinous, and tasteless. It is odorless when dry, but has a sour odor when green.

NATURAL DEFECTS

Black knots and dark streaks are the most striking features in the appearance of western hemlock lumber. The black knots, which are dark brown or black, are sound and of frequent occurrence. Whereas black knots in the lumber of some species loosen and fall out during seasoning or remanufacture, those of western hemlock usually hold their places firmly. The dark streaks, sometimes called black check, occur frequently in western hemlock. They consist of dark-brown or black scars resulting from the work of the hemlock bark maggot (*10*) in the living tree. In edge-grain boards the scars appear as thin streaks or seams and in flat-grain boards as bark pockets. (Pl. 2.) The streaks ordinarily are so narrow that they are not considered as defects in any grade in edge-grain lumber. The bark pockets are not considered defects in the common grades of lumber.

Western hemlock does not commonly have certain defects common to many species of wood. The normal wood is free of resin ducts;[4] consequently the lumber never shows pitch beads, pitch pockets, or other pitch defects. Spiral grain, which is the cross grain resulting from the spiral arrangement of the fibers in growth around the tree trunk, is generally believed to occur less frequently in western hemlock than in the species which grow with western hemlock in the forest. Blue sap stain, so common in many species of the softwoods, as a rule causes little discoloration in western hemlock.

Defects common to all species of wood, such as knots, rot, shake, and checks, occur, of course, in western hemlock. The available data on the occurrence of defects in western hemlock as compared with other species of wood are very limited and do not permit close comparisons. A study of the characteristic defects of the principal softwood species including western hemlock is now under way, and data for more definite comparisons will soon be available at the Forest Products Laboratory.

CHARACTERISTICS WHICH DISTINGUISH WESTERN HEMLOCK FROM OTHER SPECIES OF WOOD

Western hemlock lumber differs so much in odor and color from the cedars and the junipers, in color from redwood and cypress, and in general structure from the hardwoods, that it is not likely to be mistaken for any of them. It is distinguishable from Douglas fir and western larch by the lighter color of the heartwood, the lack of differences in color between the sapwood and the heartwood, and by

[4] Occasionally, as the result of injury to living trees, resin ducts are formed in western hemlock as in other nonresinous softwoods. In so far as the use of the wood is concerned, they are of no practical importance.

the less pronounced summer wood, as well as by the lack of resin ducts and pitch defects. The freedom from resin ducts and pitch also serves to distinguish it from the pines and the spruces.

The principal species with which western hemlock is likely to be confused are noble fir, white fir, lowland white fir, silver fir, eastern hemlock, and California red fir (not Douglas fir). Western hemlock usually can be distinguished from the true firs by its somewhat darker color, especially of the spring wood, also by the reddish-brown tint of the summer wood as contrasted with the lavender tint of the true firs. Where the difference in color is so slight as to render identification by color impossible, resort must be made to structural differences which are visible only under the microscope.[5] In bulk, however, unmixed lots of the true firs and western hemlock are easier to identify, for color differences are more pronounced when the woods are in bulk.

Individual pieces of eastern and western hemlock can not be positively distinguished from each other, even under the microscope, unless the dark streaks common to the western species are present. Western hemlock in bulk, however, may be roughly distinguished from the eastern species; not only is the average width of the annual rings of the western species more uniform, but there is less contrast in color between the spring wood and summer wood. (Pl. 3.)

GRADES AND THEIR CHARACTERISTICS

Rules applying to the classification, manufacture, and grading of lumber cut from western hemlock are published by the West Coast Lumbermen's Association (*33*). The rules for yard lumber, or lumber suitable for general building purposes, follow the basic grade classification of American lumber standards except for the addition of a grade of Selected Common (*29*).

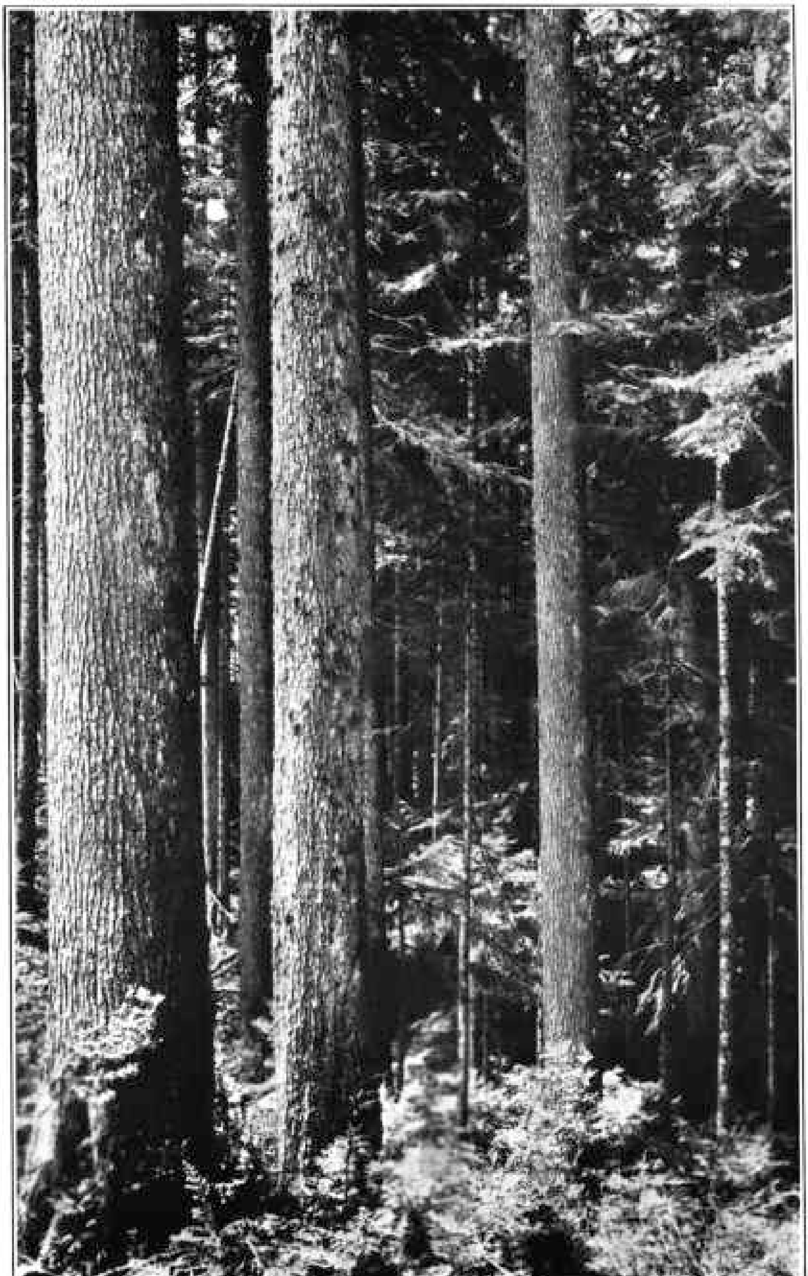
SELECT GRADES

The select grades, listed as "clears" in the grading rules of the West Coast Lumbermen's Association, have a good appearance and are suitable for both natural and paint finishes. They include A, B and Better, B, C, and D. Items, such as western hemlock finish, casing and base, siding, ceiling, and partition, are manufactured in the B and Better, C, and D grades. Flooring of western hemlock is produced in the A and B grades, as well as in other select grades.

The high quality of B and Better and its suitability for natural finishes are shown in Plate 4, A. The grade allows only a few small defects or blemishes. Except a limited number of small, tight pin knots in siding, ceiling, partition, and flat-grain flooring, knots are not permitted in this grade. Slight torn grain and very small bark pockets are permitted in all items, and limited end split and slight cup in finish, casing, and base.

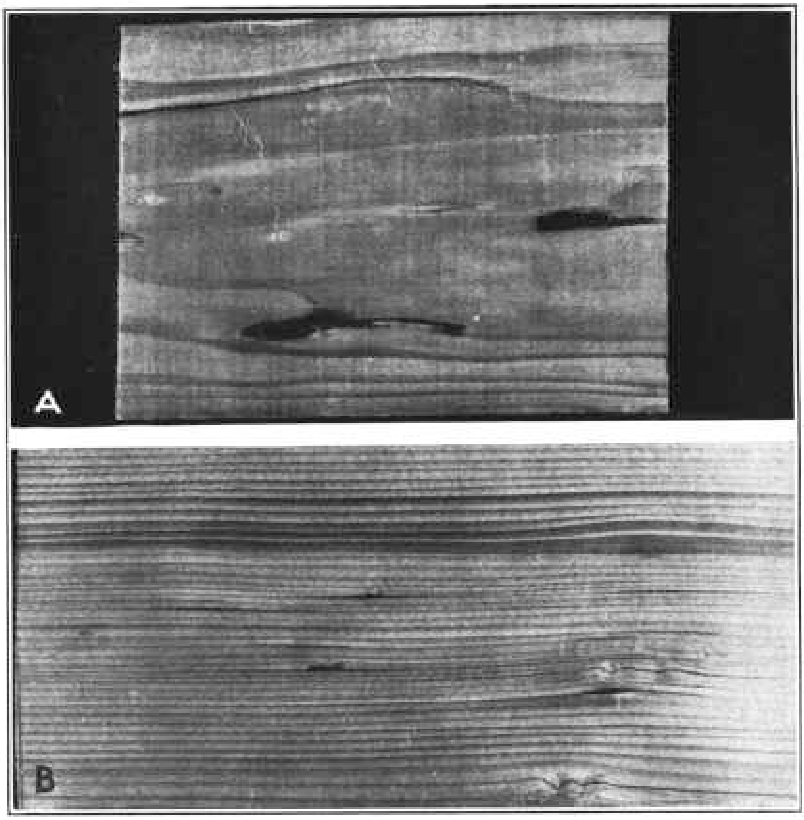
The C grade provides a good stock for paint finishes, especially for enamel, also a large amount of material suitable for natural finishes. It permits only a limited amount of small defects or blemishes, which can be covered satisfactorily with paint. It differs from B and

[5] Where there is doubt as to the identity of wood, samples may be submitted for identification to the Forest Products Laboratory, Madison, Wis.



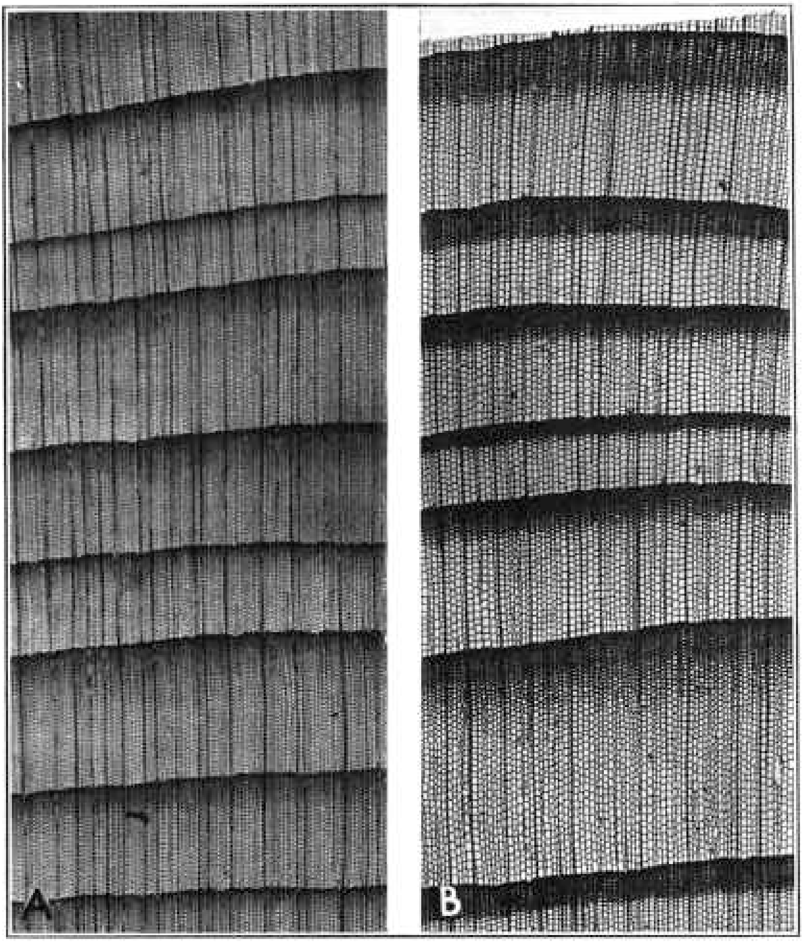
A VIRGIN FOREST OF WESTERN HEMLOCK

The three most prominent trees are western hemlock of approximately 40 inches diameter.



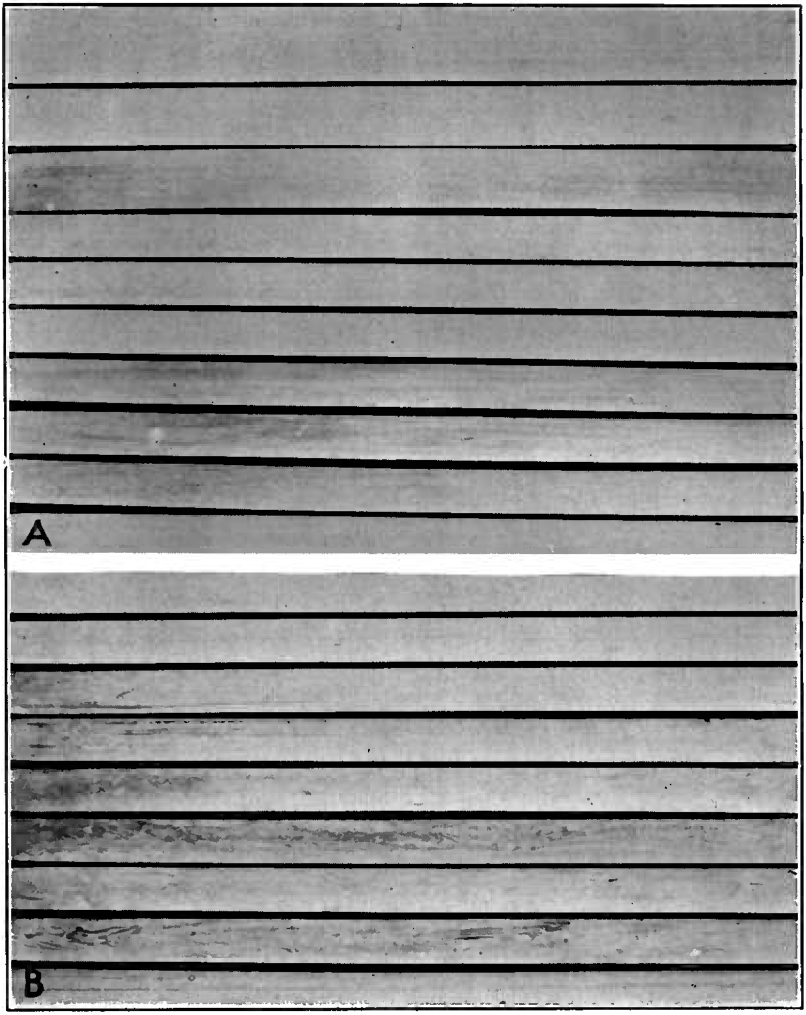
CHARACTERISTIC FEATURES OF WESTERN HEMLOCK

A.—Dark streak appears on the flat grain as small bark pockets.
B.—Dark streak appears on the edge grain as fine dark-colored lines or streaks. Such dark streak is not a defect in any lumber grade.



COMPARISON OF END-GRAIN WESTERN AND EASTERN HEMLOCK (MAGNIFIED 20 DIAMETERS)

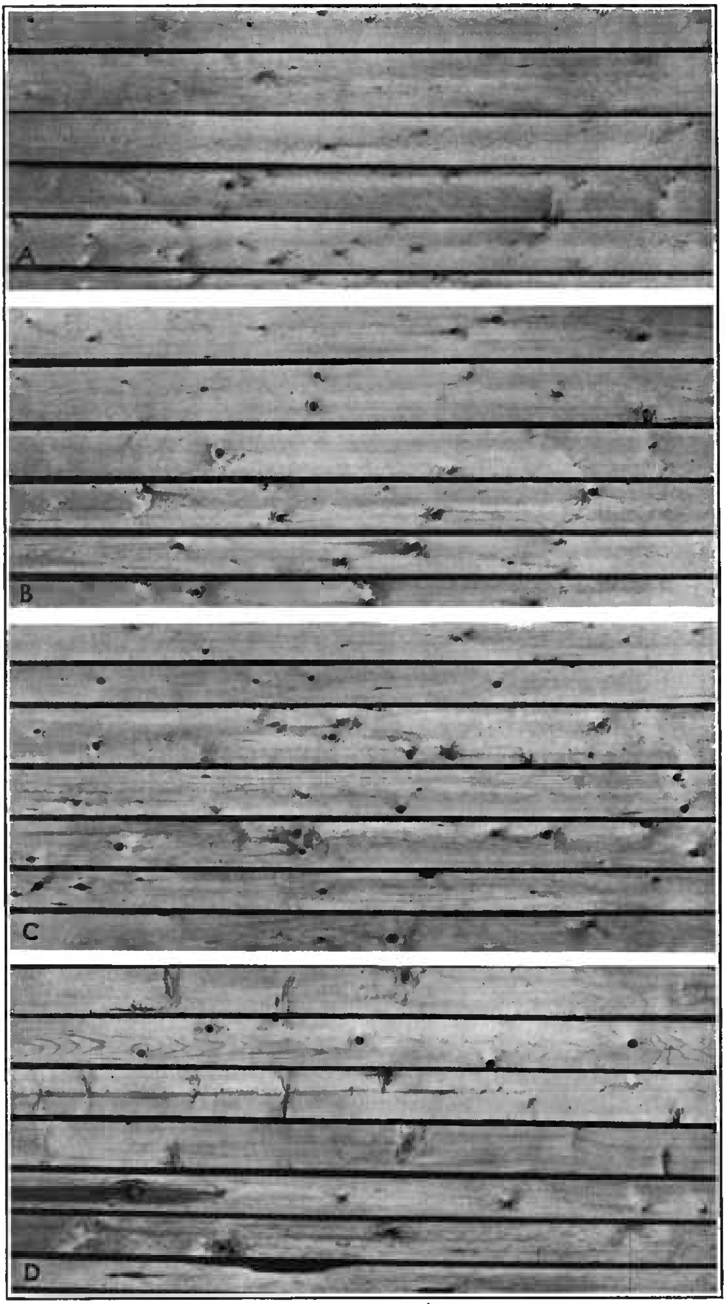
A.—Western hemlock.
B.—Eastern hemlock.
Western hemlock generally has narrower and less sharply defined summer-wood bands, and its growth rings are more uniform in width than those of eastern hemlock. Individual specimens of either species vary widely in these respects.



SELECT GRADES OF WESTERN HEMLOCK

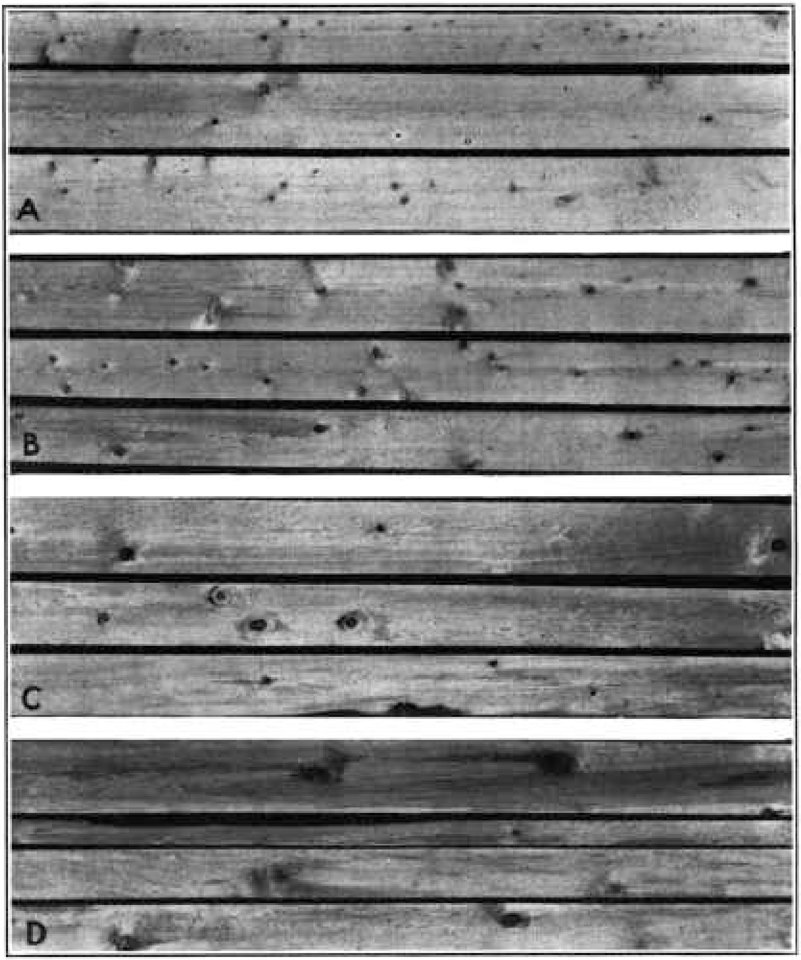
A.—B and Better finish. The only natural defects permitted are very small bark pockets under one-eighth inch wide and less than 2 inches long. A practically clear grade suitable for natural finishes.

B.—C finish. A good paint grade. Suitable for interior finish, especially enamel. The natural defects permitted are small knots under three-fourths inch in diameter and small bark pockets both of which are shown.



COMMON GRADES OF WESTERN HEMLOCK BOARDS

A.—Selected Common. A sound, tight, square edge grade suitable for finishes otber tban enamel. Knots are intergrown and less tban 1½ inches in diameter.
B.—No. 1 Common. A tigbt grade suitable for general use. Knots are tight, sound, but not necessarily intergrown, and from 1½ to 3 inches in diameter.
C.—No. 2 Common. A grade suitable for use as a wbole. It is neither grain-tigbt nor water-tight. Permits unsound knots and a limited number of knot boles under 1½ inches in diameter.
D.—No. 3 Common. Suitable for sheatbing, but may invo ve some waste from wane or decay spots such as are shown.



DIMENSION GRADES OF WESTERN HEMLOCK

A.—Selected Common. Knots limited but cross grain and split not limited as in the basic provision for Select Structural grade of American lumber standards. Suitable for use where bending strength is desired.
B.—No. 1 Common. Knots limited but cross grain and split not limited as in the basic provision for Common Structural grades of American lumber standards. Suitable for use where bending strength is desired.
C.—No. 2 Common. Unsound knots and limited decay permitted. Suitable for joists and other uses where stiffness rather than bending strength is desired.
D.—No. 3 Common. Decay spots permitted. Knot sizes not limited. Suitable for use in temporary work.

Better in that a limited number of small tight knots are permitted in practically all items, also varying but limited amounts of light sap stain. The grade, moreover, allows a limited number of small season checks, also slightly more torn grain, skips, and bark pockets than B and Better. As it is actually marketed, there is relatively little sap stain in the C grade of western hemlock largely because the species has a very narrow sap ring. The small knots and bark pockets characteristic of the grade are shown in some of the specimens of Plate 4, B.

Although the lumber in the D grade must be suitable for paint finishes, many defects and blemishes are allowed. This grade is of relatively little importance in western hemlock, at least at present. The amount of potential D stock is small, and the bulk of it now goes into common lumber.

COMMON GRADES

Yard lumber suitable for general utility and construction purposes, but not for finishing uses, falls in either the common grades of boards or dimension stock. The common grades, produced in such items as common boards, shiplap, and dressed and matched stock, include Selected Common, No. 1 Common, No. 2 Common, and No. 3 Common. Numerous small and medium-sized red and black knots, together with bark pockets and dark streaks are characteristic of all the common grades.

Selected Common is a sound, tight-knotted stock suitable for paint jobs of less exacting requirements than interior finish. The grade differs from the select grades in that there is no limit on the number of natural defects permitted and from the common grades in that only intergrown [6] knots are permitted. While all the knots of this grade are intergrown, their size and number, together with other defects, preclude its use for high-grade finishes. Knots are limited by the grading rules to 1 inch in diameter in 4 to 6 inch widths, and to 1½ inches in 8 to 12 inch widths. As actually marketed, Selected Common western hemlock usually contains much less sap stain and smaller bark pockets than are permitted by the grade description. The characteristics of the grade are shown in Plate 5, A.

The No. 1 Common grade may be considered a water-tight stock suitable for use without waste as sheathing, roofing, or subflooring. It may be either Douglas fir or western hemlock or both.[7] The knots are both sound [8] and tight [9] (*29*), but not necessarily intergrown; their diameters are limited to 1½ inches in 4 to 6 inch widths and to 3 inches in 12-inch and wider stock. Wane may be ½ inch deep on edge, 1 inch wide on face, and one-sixth of the length of the piece. All of the specimens in Plate 5, B, are No. 1 Common because of the size or character of the knots.

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[6] An intergrown knot is one whose rings of annual growth are completely intergrown with those of the surrounding wood.

[7] The practice of mixing species in grades below Selected Common arose from the difficulties encountered in the past in marketing western hemlock under its own name. and from the fact that many mills did not cut sufficient lumber of species other than Douglas fir to warrant their segregation. The practice of mixing is decreasing, but there will probably always be some mills whose cut of hemlock will be too small to justify its segregation.

[8] A sound knot is solid across its face, as hard as the surrounding wood, and shows no indication of decay. It may vary in color from red to black.

[9] A tight knot is one so fixed by growth or position that it will firmly retain its place in the piece.

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No. 2 Common, with some cutting to eliminate defects, is considered to give a grain-tight lumber. It is suitable for subfloors, sheathing, grain doors, and the like. The knots are larger than those in No. 1 Common, and differ somewhat in character. Their diameters are limited to 2 inches in 4 to 6 inch widths, increasing gradually to 4 inches in 12-inch and wider stock. Unsound [10] but tight knots and medium-sized incased [11] knots are permitted in the grade, also two medium or equivalent smaller knot holes where other defects are limited. The general character of the grade is illustrated in Plate 5, C.

No. 3 Common, as shown by Plate 5, D, is neither grain nor watertight. Without cutting it is suitable only for low-grade sheathing or similar uses. Large, loose, and unsound knots and knot holes in unlimited number together with wane, shake, sap stain, decayed spots, and streaks are characteristics of the grade. Variation in thickness and splits not longer than one-fourth the length of the piece are also permitted. The grade will admit any or all species associated with western hemlock in the forest.

DIMENSION GRADES

The description of the common grades just given applies to western hemlock boards, but does not apply to dimension stock, although the dimension grades are sold under the same names.

Selected Common dimension admits only western hemlock. No. 1 Common in sizes up to 2 by 6 inches and No. 2 Common in all sizes admit Douglas fir, western hemlock, or both. No 3 Common admits all species associated with western hemlock in the forest. In the grades and sizes where western hemlock is mixed with Douglas fir, the strength value of the grade for structural purposes should be based on the hemlock rather than on the Douglas fir.

The knots in Selected Common and No. 1 Common western hemlock dimension (pl. 6, A, B) are limited with a view to requirements where strength is desired and appearance is of minor importance, such as in joist, plank, and studding. However, the Selected Common and the No. 1 Common dimension western hemlock grades of the West Coast Lumbermen's Association contain no limitations on cross grain and permit splits which may not be allowed under the American lumber standards (*29*); consequently, some material in these grades can not take the stresses recommended in Table 1 for use with grades meeting the basic provisions of American lumber standards for joist and plank.

No stress recommendations are made by the Forest Products Laboratory for No. 2 Common and No. 3 Common western hemlock dimension. (Pl. 6, C, D.) No. 2 Common western hemlock dimension, with some culling of pieces with the worst defects, especially those with large knots on the edges, is suitable for joists and studding in small-house construction where stiffness rather than strength is the controlling factor.

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[10] An unsound knot is solid across its face, but contains incipient decay.

[11] An incased knot is one whose rings of annual growth are not intergrown and homogeneous with those of the surrounding wood. The incasement may be partial or complete and may be pitch or bark.

FACTORY AND BOX GRADES

Factory and box lumber grades are based on the percentage of cuttings obtainable for specified purposes. The size and character of the cuttings required in western hemlock are the same as those of other species; a discussion of the grades is therefore omitted.

STRUCTURAL GRADES AND THEIR WORKING STRESSES

The standard-grading rules (*33*) of the West Coast Lumbermen's Association contains no structural grade for western hemlock, however, the basic provisions of the American lumber standards (*29*) for structural material apply to western hemlock as well as to other species.

When provisions are made for controlling the size, number, and location of defects in relation to their injurious effect on the strength of clear wood, as is necessary in structural grades, it is possible to assign values for use in design. These are called working stresses and are used for such purposes as the basis for building codes or other engineering specifications. Working stresses are applicable only to specified grades, except in the cases of modulus of elasticity and compression perpendicular to the grain. Values for these two properties are applicable to all grades. Working stresses for western hemlock and a number of other important species of wood are presented in Table 1 for the select and common grades and are shown in Figures 4 to 8 for the Common grade.

TABLE 1.—*Working stresses, in pounds per square inch, for timber conforming to the basic provisions for select and common structural material of American lumber standards* [1]

[As recommended by the Forest Products Laboratory, Forest Service, United States Department of Agriculture]

Species	Fiber stress in bending [2]										Compression perpendicular to grain			Horizontal shear [3]		Compression parallel to grain (short columns having ratio of length to least dimension of 11 or less)						Average modulus of elasticity [4]
	Continuously dry		Occasionally wet but quickly dried				More or less continuously damp or wet				Continuously dry	Occasionally wet but quickly dried	More or less continuously damp or wet	Not varied with conditions of exposure		Continuously dry		Occasionally wet but quickly dried		More or less continuously damp or wet		Not varied with conditions of exposure or with grade
	All thicknesses		Material 4 inches and thinner		Material 5 inches and thicker		Material 4 inches and thinner		Material 5 inches and thicker													
	Select grade	Common grade	Select grade	Common grade	Select grade	Common grade	Select grade	Common grade	Select grade	Common grade	Select and Common grades			Select grade	Common grade	Select grade	Common grade	Select grade	Common grade	Select grade	Common grade	
Ash, black	1,000	800	800	680	900	720	710	600	800	640	300	200	150	90	72	650	520	550	440	500	400	1,100,000
Ash, commercial white	1,400	1,120	1,070	910	1,200	960	890	760	1,000	800	500	375	300	125	100	1,100	880	1,000	800	900	720	1,500,000
Aspen and large-tooth aspen	800	640	580	490	650	520	440	370	500	400	150	125	100	80	64	700	560	550	440	450	360	900,000
Basswood	800	640	580	490	650	520	440	370	500	400	150	125	100	80	64	700	560	550	440	450	360	900,000
Beech	1,500	1,200	1,150	980	1,300	1,040	890	760	1,000	800	500	375	300	125	100	1,200	960	1,100	880	900	720	1,600,000
Birch, paper	900	720	670	570	750	600	530	450	600	480	200	150	100	80	64	650	520	550	440	450	360	1,000,000
Birch, yellow and sweet	1,500	1,200	1,150	980	1,300	1,040	890	760	1,000	800	500	375	300	125	100	1,200	960	1,100	880	900	720	1,600,000
Cedar, Alaska	1,100	880	890	760	1,000	800	800	680	900	720	250	200	150	90	72	800	640	750	600	650	520	1,200,000
Cedar, western red	900	720	710	600	800	640	670	570	750	600	200	150	125	80	64	700	560	700	560	650	520	1,000,000
Cedar, northern and southern white	750	600	580	490	650	520	530	450	600	480	175	140	100	70	56	550	440	500	400	450	360	800,000
Cedar, Port Orford	1,100	880	890	760	1,000	800	800	680	900	720	250	200	150	90	72	900	720	825	660	750	600	1,200,000
Chestnut	950	760	760	650	850	680	620	530	700	560	300	200	150	90	72	800	640	700	560	600	480	1,000,000
Cottonwood, eastern and black	800	640	580	490	650	520	530	450	600	480	150	125	100	80	64	700	560	550	440	450	360	900,000
Cypress, southern	1,300	1,040	980	830	1,100	880	800	680	900	720	350	250	225	100	80	1,100	880	1,000	800	800	640	1,200,000
Douglas fir (western Washington and Oregon type) [5]	1,600	1,200	1,233	983	1,387	1,040	948	756	1,067	800	[6] 347	[6] 240	[6] 213	90	72	1,173	880	1,067	800	907	680	1,600,000
Douglas fir (dense) [5]	1,750	1,400	1,349	1,147	1,517	1,213	1,037	882	1,167	933	379	262	233	105	84	1,283	1,027	1,167	933	992	793	1,600,000
Douglas fir (Rocky Mountain type)	1,100	880	800	680	900	720	620	530	700	560	275	225	200	85	68	800	640	800	640	700	560	1,200,000
Elm, rock	1,500	1,200	1,150	980	1,300	1,040	890	760	1,000	800	500	375	300	125	100	1,200	960	1,100	880	900	720	1,300,000
Elm, slippery and American	1,100	880	800	680	900	720	710	600	800	640	250	175	125	100	80	800	640	750	600	650	520	1,200,000

Fir, balsam	900	720	670	570	750	600	530	450	600	480	150	125	100	70	56	700	560	600	480	500	400	1,000,000
Fir, commercial white	1,100	880	800	680	900	720	710	600	800	640	300	225	200	70	56	700	560	700	560	600	480	1,100,000
Gum, red, black, and tupelo	1,100	880	800	680	900	720	710	600	800	640	300	200	150	100	80	800	640	750	600	650	520	1,200,000
Hemlock, eastern	1,100	880	800	680	900	720	710	600	800	640	300	225	200	70	56	700	560	700	560	600	480	1,100,000
Hemlock, western	1,300	1,040	980	830	1,100	880	800	680	900	720	300	225	200	75	60	900	720	900	720	800	640	1,400,000
Hickory (true and pecan)	1,900	1,520	1,330	1,130	1,500	1,200	1,070	910	1,200	960	600	400	350	140	112	1,500	1,200	1,200	960	1,000	800	1,800,000
Larch, western	1,200	960	980	830	1,100	880	800	680	900	720	325	225	200	100	80	1,100	880	1,000	800	800	640	1,300,000
Maple, sugar and black	1,500	1,200	1,150	980	1,300	1,040	890	760	1,000	800	500	375	300	125	100	1,200	960	1,100	880	900	720	1,600,000
Maple, red and silver	1,000	800	800	680	900	720	620	530	700	560	350	250	200	100	80	800	640	700	560	600	480	1,100,000
Oak, commercial red and white	1,400	1,120	1,070	910	1,200	960	890	760	1,000	800	500	375	300	125	100	1,000	800	900	720	800	640	1,500,000
Pine, southern yellow [5]	------	1,200	------	983	------	1,040	------	756	------	800	(6)	(6)	(6)	------	88	------	880	------	800	------	680	1,600,000
Pine (dense) [5]	1,750	1,400	1,349	1,147	1,517	1,213	1,037	882	1,167	933	379	262	233	128	103	1,283	1,027	1,167	933	992	793	1,600,000
Pine, northern white, western white, western yellow, and sugar	900	720	710	600	800	640	670	570	750	600	250	150	125	85	68	750	600	750	600	650	520	1,000,000
Pine, Norway	1,100	880	890	760	1,000	800	710	600	800	640	300	175	150	85	68	800	640	800	640	700	560	1,200,000
Poplar, yellow	1,000	800	800	680	900	720	710	600	800	640	250	150	125	80	64	800	640	700	560	600	480	1,100,000
Redwood	1,200	960	890	760	1,000	800	710	600	800	640	250	150	125	70	56	1,000	800	900	720	750	600	1,200,000
Spruce, red, white, and Sitka	1,100	880	800	680	900	720	710	600	800	640	250	150	125	85	68	800	640	750	600	650	520	1,200,000
Spruce, Engelmann	750	600	580	490	650	520	440	370	500	400	175	140	100	70	56	600	480	550	440	450	360	800,000
Sycamore	1,100	880	800	680	900	720	710	600	800	640	300	200	150	80	64	800	640	750	600	650	520	1,200,000
Tamarack (eastern)	1,200	960	980	830	1,100	880	800	680	900	720	300	225	200	95	76	1,000	800	900	720	800	640	1,300,000

[1] American lumber standards: Basic provisions for American lumber standards grades are published by the U. S. Department of Commerce in Simplified Practice Recommendation No. 16 (*29*); specifications for grades conforming to American lumber standards are published in the 1927 Standards of the American Society for Testing Materials, and in Amer. Ry. Engr. Assoc. Bul. (*3*).

[2] Stress in tension: The working stresses recommended for fiber stress in bending may be safely used for tension parallel to grain.

[3] Joint details: The shearing stresses for joint details may be taken for any grades as 50 per cent greater than the horizontal shear values for the Select grade.

[4] Factors to be applied to average modulus of elasticity values: The values for modulus of elasticity are average for species and not safe working stresses. They may be used as given for computing average deflection of beams. When it is desired to prevent sag in beams values one-half those given should be used. In figuring safe loads for long columns values one-third those given should be used.

[5] Exact figures given: In order to preserve the exact numerical relations among working stresses for grades involving rate of growth and density requirements the values for Douglas fir (western Washington and Oregon type) and for southern yellow pine have not been rounded off, as have the values for the other species.

[6] Working stresses for the Common grade: The values given are for the Select grade. Working stresses in compression perpendicular to grain for the common grades of Douglas fir (western Washington and Oregon type) and southern yellow pine are 325, 225, and 200, respectively, for continuously dry, occasionally wet but quickly dried, and more or less continuously damp or wet conditions.

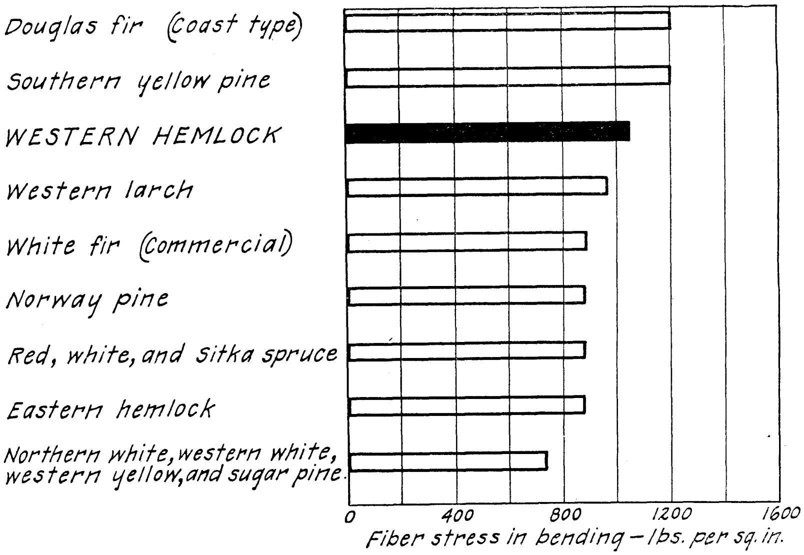

FIGURE 4.—Safe working fiber stress in bending for use in continuously dry locations. Applicable only to material meeting the defect limitations for structural material of common grade under the American lumber standards. (Working stresses should not be used for comparisons of clear wood. Comparisons of clear wood may be made from Table 2)

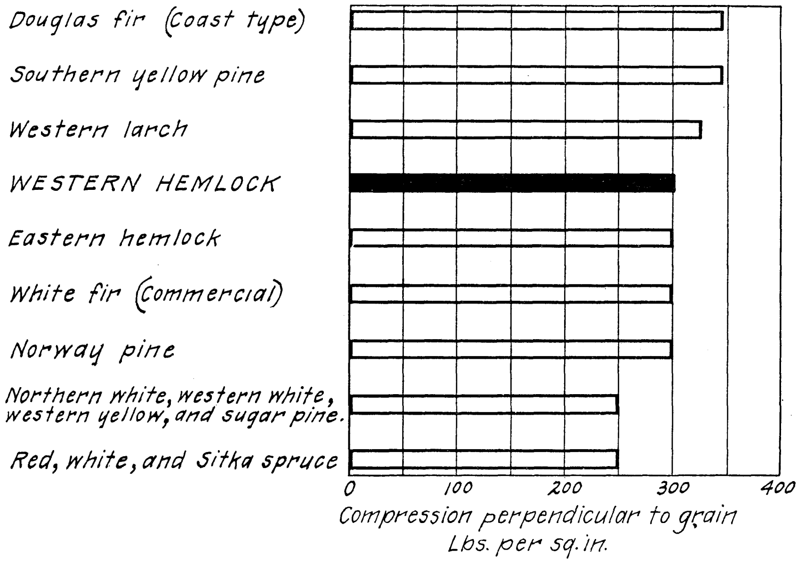

FIGURE 5.—Safe working stress for compression perpendicular to grain for use in continuously dry locations. Applicable to all commercial grades. (Working stresses should not be used for comparisons of clear wood. Comparisons of clear wood may be made from Table 2)

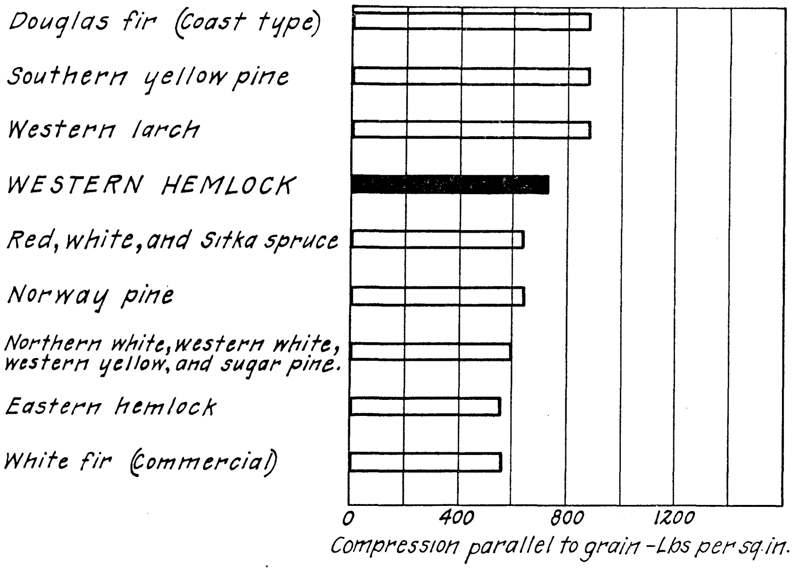

FIGURE 6.—Safe working stress for compression parallel to grain for use in continuously dry locations. Applicable to posts, caps, sills, timbers, etc., 6 by 6 inches and larger which meet the basis requirements for common grade of the American lumber standards. (Working stresses should not be used for comparisons of clear wood. Comparisons of clear wood may be made from Table 2)

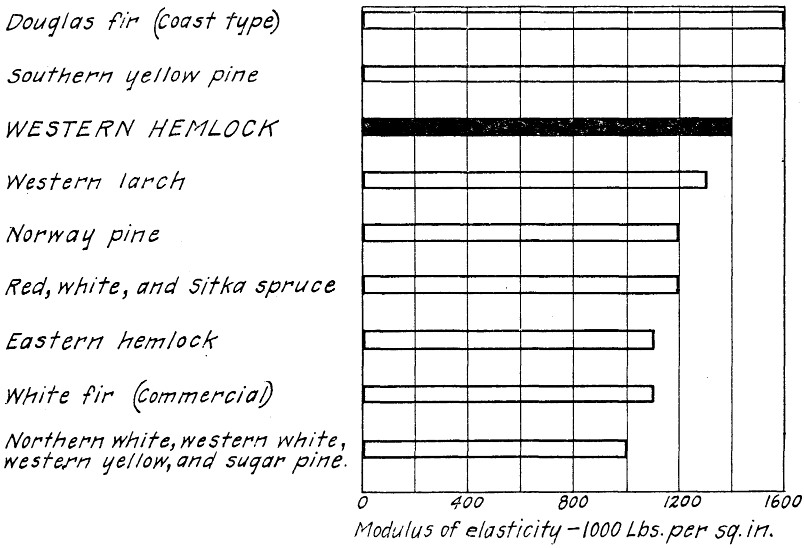

FIGURE 7.—Average values for modulus of elasticity for use under all conditions of exposure. Applicable to all commercial grades. These values are not safe working stresses. (See footnote 4, Table 1)

The working stresses were obtained by adjusting the results of strength tests to conditions that exist in actual service. This adjustment has included a number of factors (*18*, *25*, *28*), the most important of which are the possible reduction in strength that may result from the defects, the occurrence of pieces below the average strength, the decrease in load-carrying capacity due to the relatively long time that timbers in service are required to sustain a load as compared with the time test specimens are required to sustain loads, and the provision for small accidental overloads that may come on a structure. In a structure designed from the stresses recommended in Table 1 occasional timbers may be expected to fail immediately upon being subjected to twice their design loads; the average timber, however, will carry about two and one-fourth times the design load for a long period; that is, about 10 years, provided decay does not impair the load-carrying capacity sufficiently to require replacement. About one timber in a hundred will fail at one and one-half times the design load if the load remains on the structure for about 10 years.

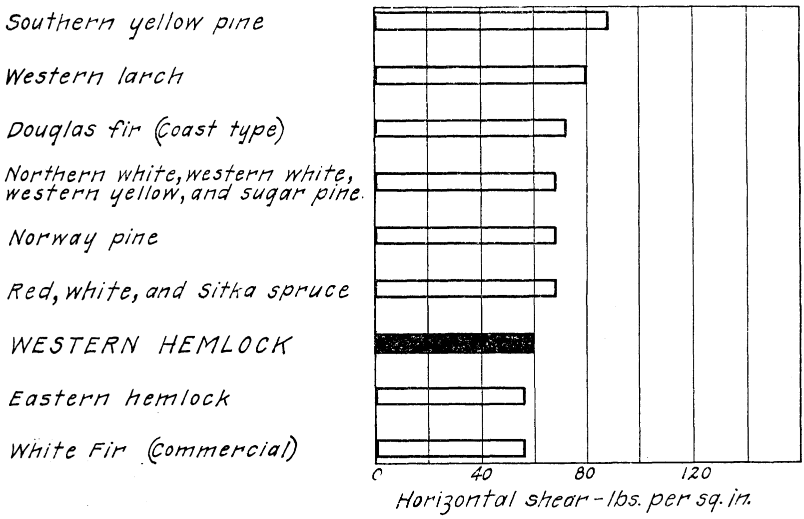

FIGURE 8.—Safe working stress for horizontal shear for use under all conditions of exposure. Applicable only to material meeting the defect limitations required for structural material of common grade under the American lumber standards. (Working stresses should not be used for comparisons of clear wood. Comparisons of clear wood may be made from Table 2)

The values for modulus of elasticity given in the table are not working stresses. They are applicable to all grades and all conditions of service and are intended for use in computing the probable deflection of beams under short-time loads. Where it is desired to minimize the sag, values only one-half of those given in the table should be used. When used to compute the safe load-carrying capacity of long or Euler columns, modulus of elasticity values only one-third of those given in the table should be used.

MECHANICAL AND PHYSICAL PROPERTIES

COMPARISON OF CLEAR WOOD OF WESTERN HEMLOCK WITH OTHER SPECIES OF WOOD

A comparison of the properties of western hemlock with those of other well-known species of wood has been chosen as the most readily understandable way of describing the species. Such comparisons are therefore made in the text, in graphs, and in tables. Table 2 is intended primarily for the comparison of western hemlock with other species of wood. With respect to each one of several properties, 100 points has been chosen to represent western hemlock, so that the comparison with other species can be made at a glance. Thus a species represented by 94 points is 6 points lower than western hemlock, and one represented by 122 is 22 points higher. Comparisons thus made are of the inherent unit properties of the clear wood of the species and take no consideration of such factors as grade, defects, or size, which in actual practice may characterize or be associated with different species of wood.

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TABLE 2.—*Average mechanical and physical properties of clear wood of western hemlock compared with other species* [1]

Species of wood	Specific gravity based on oven-dry weight and green volume	Weight per cubic foot		Composite or index values [2] (western hemlock taken as 100 points) for—						Strength at 12 per cent moisture content	
		Green	Air dry 12 per cent moisture	Bending strength	Compressive strength (endwise)	Stiffness	Hardness	Shock resistance	Shrinkage	Modulus of rupture	Compression parallel to grain
		Pounds	*Pounds*	*Points*	*Points*	*Points*	*Points*	*Points*	*Points*	*Lbs. per sq. in.*	*Lbs. per sq. in.*
Chestnut (Castanea dentata)	0.40	55	30	92	83	78	100	95	92	8,800	5,520
Cedar, western red (Thuja plicata)	.31	27	23	81	88	75	76	71	63	7,800	5,120
Cypress, southern (Taxodium distichum)	.42	50	32	107	110	94	104	104	87	10,610	6,390
Douglas fir, Coast type (Pseudotsuga taxifolia)	.45	38	34	122	127	126	118	111	101	11,920	7,590
Fir, white [3]	.35	41	26	97	91	98	82	90	92	9,550	5,540
Hemlock, eastern (Tsuga canadensis)	.38	50	28	97	94	84	102	92	82	8,950	5,490
Hemlock, western (Tsuga heterophylla)	.38	41	29	100	100	100	100	100	100	9,990	6,200
Larch, western (Larix occidentalis)	.48	48	36	120	124	106	128	111	107	11,790	7,480
Oaks, commercial white [4]	.59	63	47	134	111	103	218	171	129	13,990	7,060
Pine, Norway (Pinus resinosa)	.44	42	34	115	108	113	92	115	97	12,550	7,250
Pine, loblolly (Pinus taeda) [5]	.50	54	38	126	124	115	124	127	106	13,000	8,200
Pine, longleaf (Pinus palustris) [5]	.55	50	41	143	147	131	152	141	103	15,490	9,060
Pine, sugar (Pinus lambertiana)	.35	51	25	86	81	78	76	75	66	8,060	4,770
Pine, western white (Pinus monticola)	.36	35	27	93	89	95	70	89	98	9,650	5,720
Pine, northern white (Pinus strobus)	.34	36	25	85	80	83	70	75	69	8,920	4,910
Pine, western yellow (Pinus ponderosa)	.38	45	28	88	82	78	82	79	81	9,320	5,340
Poplar, yellow (Liriodendron tulipifera)	.38	38	28	96	81	94	80	79	99	9,320	5,420
Redwood (Sequoia sempervirens) [6]	.41	55	30	122	124	93	118	96	54	10,800	6,600
Spruce (Picea rubra and glauca) [7]	.37	35	28	94	88	90	77	92	106	9,920	5,720
Spruce, Sitka (Picea sitchensis)	.37	33	28	97	89	100	88	104	97	10,190	5,590
Percentage above or below average which will include one-half of all material	8.0			12.0	14.0	18.0	16.0	20.0	12.0		

[1] This table is for use in comparing species either in the form of clear lumber or in grades containing like defects, except structural material. Structural material which conforms to American lumber standards should be compared by means of allowable working stresses, values for which are presented in Table 1.

[2] For derivation of composite values see the following publication: MARKWARDT, L. J. COMPARATIVE STRENGTH PROPERTIES OF WOODS GROWN IN THE UNITED STATES. U. S. Dept. Agr. Tech. Bul. 158.

[3] Includes white fir (Abies concolor), lowland white fir (A. grandis), noble fir (A. nobilis), and silver fir (A. amabilis).

[4] Average of six species.

[5] Sold commercially together with a number of other species under the name southern yellow pine.

[6] The trees on which these values are based were somewhat higher in density than the general average for the species. It is, therefore, very probable that further tests which are now under way will slightly lower the present figures, although it is not expected that this will necessitate any change in the working stresses recommended for structural timbers given in Table 1.

[7] Average for red and white spruce.

The values in Table 2 are averages from the result of many tests. The strength properties of individual pieces may vary widely from the averages shown. Therefore, the fact that western hemlock shows 6 points better than another species of wood in a certain property does not mean that every piece of western hemlock will be 6 points better than every piece of the other species of wood. A percentage figure is shown at the foot of the columns of Table 2 to indicate roughly the variation, above and below the average, which may be expected to include half of all the material of a species. To simplify the table the same percentage variation is applied to all species. Actually the percentage variation is probably different for each species. The difference in the percentage with different species, however, is probably small, and until more information is available on extent and cause of the differences only a single figure will be presented.

The figures in Table 2 for western hemlock are based on the results of 2,300 tests of specimens from Washington, Oregon, and Alaska. The figures on white fir, Douglas fir, longleaf pine, southern cypress, the oaks, western yellow pine, and the spruces are based on a larger number of tests than western hemlock, in some cases about double. On the other hand, chestnut, loblolly pine, sugar pine, and yellow poplar are based on a smaller number than western hemlock, roughly about two-thirds. Data on Norway pine and redwood are based on a much smaller number of tests, less than one-third. The amount of data on the remaining species shown in the table does not differ greatly from that on which the western hemlock figures are based. Additional tests would probably not change any of the average figures on western hemlock more than about 2¾ per cent; while the probable change in averages for species based on a larger number of tests would be less than 2¾ per cent, some values based on one-third the tests probably would be changed as much as 4 per cent.

For all except white oak, white fir, and eastern spruce, the figures shown in Table 2 are for single definite botanical species. The species of wood that are combined under the names white oak and eastern spruce are usually sold under the name given, and their strength properties are the average for a group. The commercial name "white fir" is usually applied only to white fir and lowland white fir. The strength properties given for commercial white fir in all the tables of this bulletin, however, combine not only the properties for white fir and lowland white fir but also those for noble and silver fir. The figures for longleaf and loblolly pines are for the botanical species and have no fixed or definite relation to commercial names. It is difficult, if not impossible, to arrive at a representative figure for the different commercial types of the southern pines on account of the proportion of different species going into the various commercial types. The Southern Pine Association, however, makes a distinction between dense and nondense material in structural items but not in yard lumber (*21*). It has, therefore, been possible to present group figures for southern yellow pine in Table 1, which present the working stresses for structural material.

WEIGHT AND SPECIFIC GRAVITY

Western hemlock when oven dry has an average specific gravity, which is a measure of density, of 0.38; that is, a cubic foot of western hemlock at practically zero moisture content weighs on the average 38 per cent of the weight of a cubic foot of water at 39° F. The average weight of western hemlock in a green condition is about

FIGURE 9.—Average specific gravity and weight per cubic foot of clear wood of western hemlock as compared with other species of wood. The specific gravity, or weight when in a dry condition, of western hemlock is low for its strength. The weight when in a green condition is high and variable; a condition caused by the nonuniform moisture distribution.

41 pounds per cubic foot and in an air-dry condition—that is, at about 12 per cent moisture content—it is 29 pounds per cubic foot. Air-dried material will seldom fall below 26 pounds per cubic foot but may run more than 37 pounds per cubic foot. Green material, because of a variable moisture content, may weigh as much as 60 pounds per cubic foot.

The specific gravity of western hemlock affords the quickest basis for generally comparing its strength with that of other species, for woods with a higher specific gravity are generally stronger and woods with a lower specific gravity are generally weaker. A comparison of the specific gravity and green and dry weights (12 per cent moisture content) of western hemlock with other species is shown in Figure 9.

The specific gravity of representative samples of mill-run western hemlock and four other species obtained by the random selection of thousands of specimens is shown in Figure 10. The comparison indicates that western hemlock is more uniform in specific gravity than Douglas fir and southern pine, and less uniform than Sitka spruce. From this study one would expect 50 per cent of the hemlock to have a specific gravity within about 7½ per cent of the average, and occasional pieces—about one in ten—to be 18 per cent or more above or below the average—that is, to have a specific gravity below 0.33 or above 0.47. About one piece in six of Sitka spruce was found to be as heavy as average western hemlock, while about one piece in

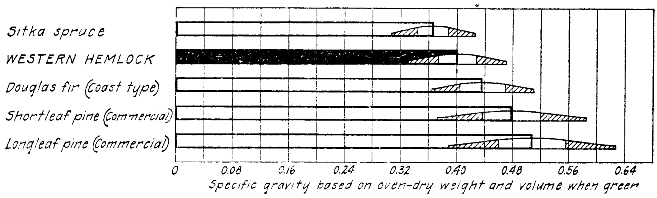


FIGURE 10.—Average value and range of specific gravity of western hemlock compared with other species of wood. Based upon a random selection from mill-run lumber. Average shown by the end of the horizontal bar and range by the area under the curve. One-half of all material of a species of wood fell within the range shown by the blank space between the crosshatched areas; 40 per cent in the range shown by the crosshatching, 20 per cent above the average and 20 per cent below the average; while 10 per cent, 5 per cent above and 5 per cent below, fell outside the range shown by the curve.

four of Douglas fir, one piece in ten of commercial shortleaf pine, and one piece in twenty of commercial longleaf was below the average specific gravity of western hemlock.

The average specific gravity of western hemlock, determined from mill-run samples (fig. 10) was 0.40, as compared with 0.38, the average specific gravity based on selected samples from selected trees. (Table 2.) Considering the difference in methods of sampling, the results agree very closely.

STRENGTH IN BENDING AND ENDWISE COMPRESSION

In so far as the clear wood is concerned, a comparison of the strength of western hemlock in bending and endwise compression with other species shows (figs. 11 and 12) that in both of these properties it is somewhat weaker than Norway pine, considerably weaker than Douglas fir (coast type), and southern yellow pine, but stronger than eastern hemlock, eastern spruce, Sitka spruce, white fir, and western yellow pine. These comparisons show the general or load-carrying capacity of the clear wood of western hemlock. They are of value in determining the suitability of the species for uses that require comparatively small and clear material, such as ladders, furniture, drying racks, and some parts of wagons, automobiles, and agricultural machinery.

HARDNESS

Western hemlock is classified as moderately soft, that is, it falls between the harder softwoods, such as Douglas fir and southern yellow pine, and the softer softwoods, such as the northern white pine and western white pine. It is very similar in hardness to eastern hemlock or chestnut, but is harder than western yellow pine and white fir. More detailed comparisons are given in Figure 13 and Table 2.

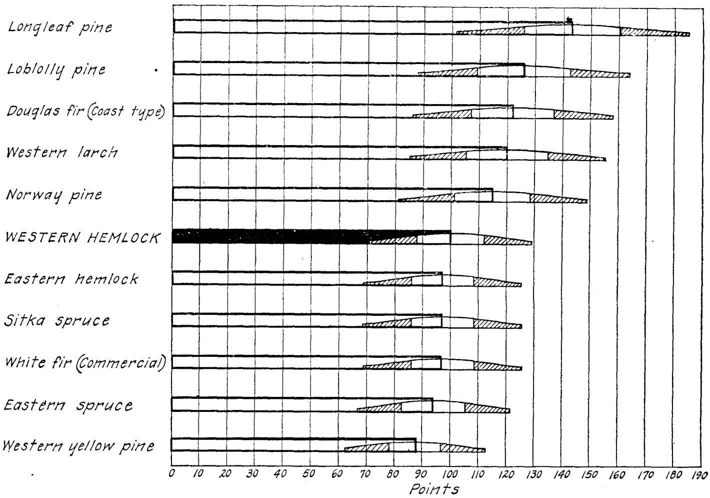


FIGURE 11.—Average value and range in bending strength of clear wood of western hemlock as compared with that of other species of wood. Western hemlock taken as 100 points. Average is shown by the end of the horizontal bar and range by the area under the curve. One-half of all material of a species of wood will fall within the range shown by the blank space between the crosshatched areas; 40 per cent in the range shown by the crosshatching, 20 per cent above the average and 20 per cent below the average; while 10 per cent, 5 per cent above and 5 per cent below, will fall outside the range shown by the curve. The comparison shown here is for clear lumber or for grades containing like defects, except structural material. The effect of defects, difference in dressed dimension, or moisture content may equalize or reverse the relative values as charted. (Structural material which conforms to the American lumber standards should be compared on the basis of working stresses, Table 1, which take into account factors other than the strength of clear wood.)

The tests on which the hardness data are based are a measure of the resistance of wood to indentation. Hardness is a better measure of the capacity of wood to withstand marring and denting than it is of capacity to withstand abrasion. Resistance to abrasion is dependent as much on the structure and coherence of fibers as upon the hardness, or even more. Since the summer wood of western hemlock is comparatively narrow and does not contrast sharply with the spring wood, the species is relatively uniform in hardness within an annual ring. In this respect western hemlock is intermediate between the hard and soft pines, but resembles the soft pines more closely than the hard pines. The lack of pronounced contrast between the spring wood and summer wood results in a surface with relatively even wearing qualities—a condition which in some uses may be as desirable as the greater hardness of some other species.

Western hemlock is sometimes used in shaped parts and in exterior trim as an alternate for softwoods of higher price. This is because of its moderate softness and because of the ease of cutting and of nailing that results from the absence of pronounced summer-wood rings; wood having such rings, which are comparatively hard, is likely to deflect edged hand tools to some extent and nails to a greater extent.

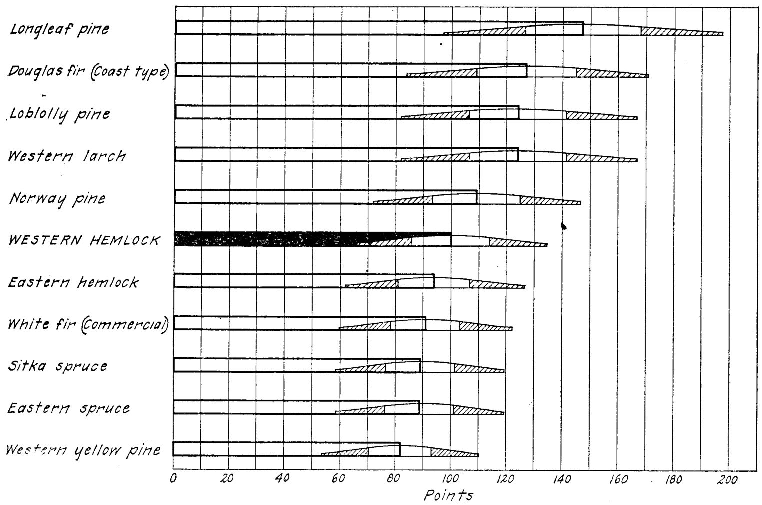


FIGURE 12.—Average value and range in compressive strength (endwise) of clear wood of western hemlock compared with that of other species of wood. Western hemlock taken as 100 points. Average is shown by the end of the horizontal bar and range by the area under the curve. One-half of all material of a species of wood will fall within the range shown by the blank space between the crosshatched areas; 40 per cent in the range shown by the crosshatching, 20 per cent above the average and 20 per cent below the average; while 10 per cent, 5 per cent above and 5 per cent below, will fall outside the range shown by the curve. The comparison shown here is for clear lumber or for grades containing like defects, except structural material. The effect of defects, difference in dressed dimension, or moisture content may equalize or reverse the relative values as charted. (Structural material which conforms to American lumber standards should be compared on the basis of working stresses, Table 1, which take into account factors other than the strength of clear wood.)

ABILITY TO WITHSTAND SHOCKS (TOUGHNESS)

In ability to resist shocks, western hemlock, in common with the other softwoods, is low as compared with the hardwoods. With most softwoods, however, it compares favorably, being slightly lower than Douglas fir and western larch, about the same as eastern hemlock and spruce, and higher than sugar pine and western yellow pine. Comparisons of this property are given in Figure 14.

Western hemlock is exceptionally high in shock resistance for its weight, a valuable characteristic in some uses, of which the ladder is a good example. Of the species listed in Table 2, Sitka spruce is the only superior to western hemlock in shock resistance for weight, and Norway pine the only equal. In comparing the shock resistance of western hemlock with that of other species, it is well to remember that where the highest possible shock resistance is desired, as in

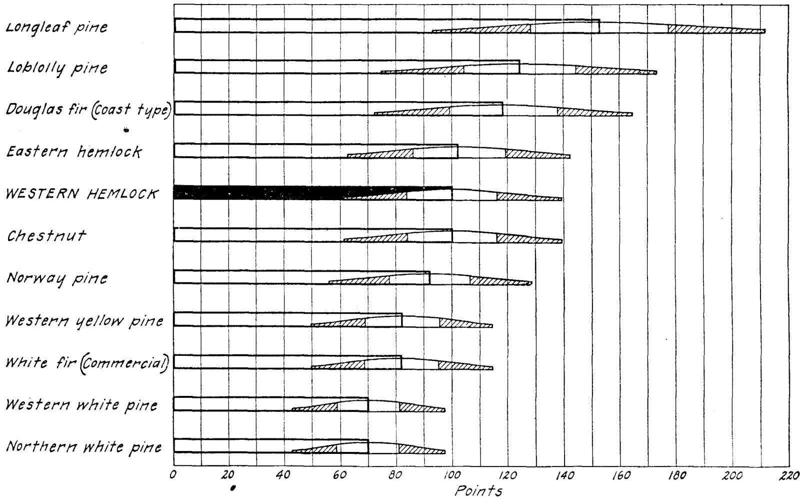


FIGURE 13.—Average value and range in hardness of clear wood of western hemlock compared with that of other species of wood. Western hemlock taken as 100 points. Average is shown by the end of the horizontal bar and range by the area under the curve. One-half of all material of a species of wood will fall within the range shown by the blank space between the crosshatched areas; 40 per cent in the range shown by the crosshatching, 20 per cent above the average and 20 per cent below the average; while 10 per cent, 5 per cent above and 5 per cent below, will fall outside the range shown by the curve. Western hemlock is moderately soft. Suitability for use requires consideration of character as well as actual hardness. The hardness of western hemlock is fairly uniform, that is, it does not consist of pronounced alternate bands of hard and soft wood. Hardness is important in ties, flooring, guides in mine shafts, and similar uses

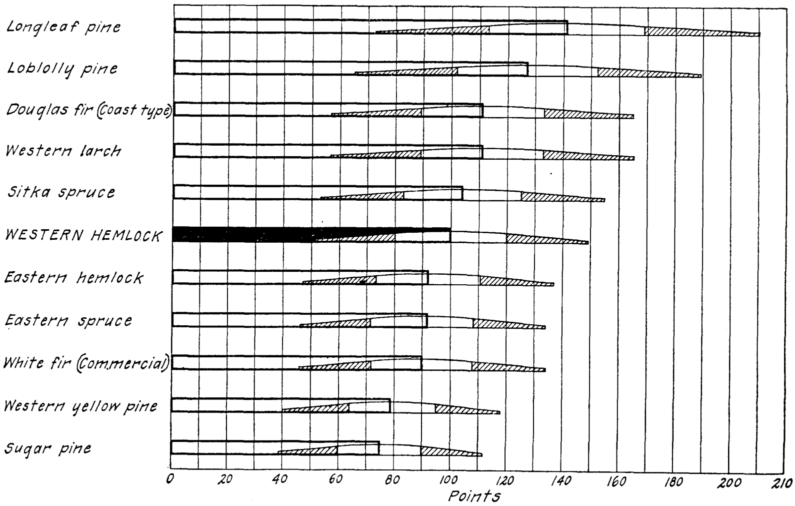


FIGURE 14.—Average value and range in capacity to withstand shocks for clear wood of western hemlock compared with that of other species of wood. Western hemlock taken as 100 points. Average is shown by the end of the horizontal bar and range by the area under the curve. One-half of all material of a species of wood will fall within the range shown by the blank space between the crosshatched areas; 40 per cent in the range shown by the crosshatching, 20 per cent above the average and 20 per cent below the average; while 10 per cent, 5 per cent above and 5 per cent below, will fall outside the range shown by the curve. The property to withstand shocks is especially influenced by such defects as knots and cross grain. It is important in ladders, boxes, implement handles, and similar uses

certain athletic goods and handles, a number of hardwoods are so much higher than western hemlock and other softwoods as to practically exclude the softwoods from such uses. On the other hand, where shock resistance combined with the lowest possible weight is desired, western hemlock is generally stronger for its weight than the hardwoods and is one of the best of the softwoods.

STIFFNESS

Western hemlock has about the same stiffness as Sitka spruce, commercial white oak, and western larch; is considerably stiffer than eastern hemlock, western yellow pine, and chestnut; but is not so stiff as Douglas fir and southern yellow pine. A graphical comparison of western hemlock with these species is shown in Figure 15.

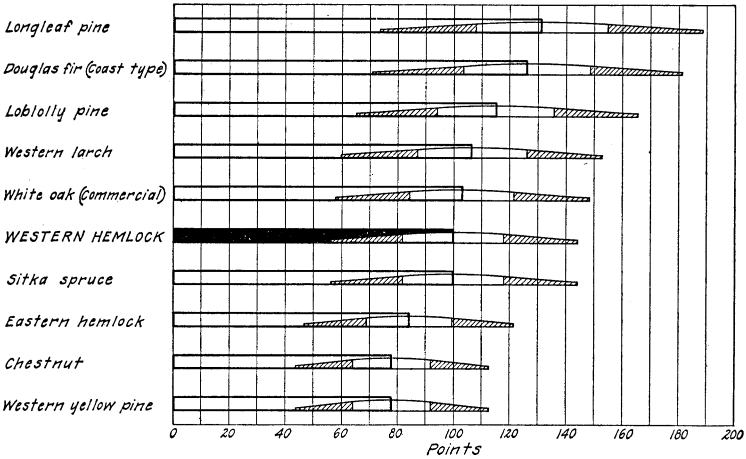


FIGURE 15.—Average value and range in stiffness of clear wood of western hemlock compared with that of other species of wood. Western hemlock taken as 100 points. Average is shown by the end of the horizontal bar and range by the area under the curve. One-half of all material of a species of wood will fall within the range shown by the blank space between the crosshatched areas; 40 per cent in the range shown by the crosshatching, 20 per cent above the average and 20 per cent below the average; while 10 per cent, 5 per cent above and 5 per cent below, will fall outside the range shown by the curve. This comparison is based on clear wood but is applicable to lumber almost as well, provided that the dressed size and moisture content are comparable, since defects have little or no influence on stiffness. (Working values for construction material, which take into consideration factors other than clear wood are shown in Table 1)

The stiffness of western hemlock is partly responsible for the amount of western hemlock lumber used in house construction, where it is important that the joists and rafters support their loads without undue deflections or vibration.

GRAIN AND TEXTURE

Western hemlock is subject to cross grain resulting from manufacturing the same as other species, since no lumber is absolutely straight grained. It has the reputation, however, of being less subject to spiral grain than Douglas fir or the spruces. The small amount of spiral grain in western hemlock is responsible for it being designated "straight grained." Spiral grain not only weakens the piece in which it occurs (*34*), but it also creates a tendency to warp.

The wood cells of western hemlock are fairly uniform in size. Although the summer-wood cells are thicker walled than those in the spring wood, there is not the contrast between spring wood and summer wood that exists in southern yellow pine, Douglas fir, and western larch, or even eastern hemlock. Western hemlock is, therefore, called a uniform, fine-textured wood. These characteristics are important in many uses, such as flooring, where uniform wear within an annual ring is desired; in boxes and crates, where a tendency of the wide summer-wood bands to deflect the nails is objectionable;

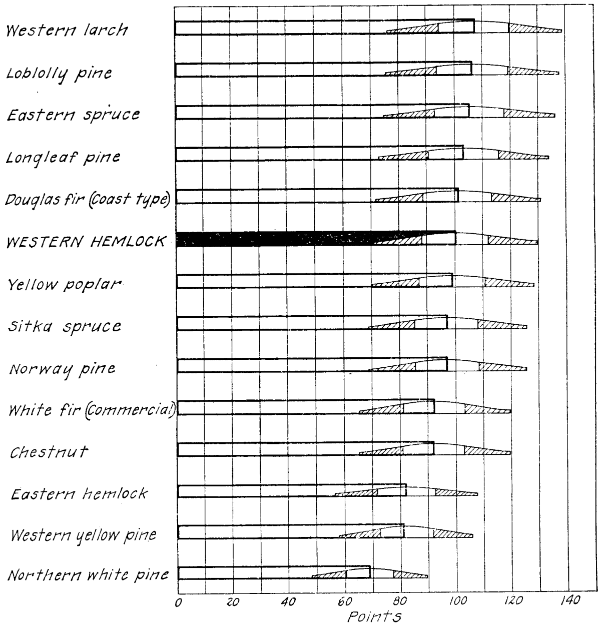


FIGURE 16.—Average value and range in the total shrinkage from a green to an oven-dry condition of small clear pieces of western hemlock as compared with that of other species of wood. Western hemlock taken as 100 points. Average is shown by the end of the horizontal bar and range by the area under the curve. One-half of all material of a species of wood will fall within the range shown by the blank space between the crosshatched areas; 40 per cent in the range shown by the crosshatching, 20 per cent above the average and 20 per cent below the average; while 10 per cent, 5 per cent above and 5 per cent below, will fall outside the range shown by the curve

and in indoor or outdoor paint or enamel finishes, where the capacity to hold a finish is essential.

SHRINKAGE

The average shrinkage for western hemlock is about the same as the amount for Douglas fir and Sitka spruce; slightly less than for western larch, loblolly pine, and eastern spruce; and more than for western yellow pine, eastern hemlock, northern white pine, and western white pine. The relative shrinkage of these and other species of wood as compared with western hemlock is shown in Figure 16 and Table 2.

The occasional practice of shipping western hemlock green and of using it before it has been sufficiently seasoned has, in some instances, led to the belief that the species shrinks more than most others. Water exists in wood in two conditions—as free water contained in the cell cavities and as water absorbed in the cell walls. When wood is dried, the free water passes off first. Water then begins to leave the cell walls, and shrinkage starts. Western hemlock contains much more water when green than Douglas fir and must dry considerably longer before shrinkage starts. When subjected to same drying conditions, western hemlock is, therefore, not likely to reach as low a moisture content as Douglas fir and thus is more likely to be put into use in a comparatively green condition. Used green, it will, like other species of wood, generally shrink sufficiently to cause trouble. The reputation thus acquired has tended to restrict its use unduly. The high moisture content of green western hemlock has no influence on its shrinkage, except in so far as it is responsible for the species being used before it is properly seasoned. Shrinkage troubles with western hemlock, as with other species of wood, can be largely controlled by proper seasoning.

Tangentially, that is, across the width of flat-sawn board, western hemlock shrinks about 8 per cent of its original width in passing from a green to an oven-dry condition. Radially, that is, across the width of a quarter-sawn or edge-grained board, it shrinks about 4¼ per cent. Practically all of the shrinkage takes place below about 29 per cent moisture content. What little shrinkage takes place above 29 per cent moisture content is due to nonuniform drying in which the outside dries below the fiber-saturation point (*23*) before the average reaches this point. Figure 17 shows how small specimens of western hemlock shrink from a green to an oven-dry condition.

The curves of Figure 17 can be used to determine the approximate average shrinkage or swelling of western hemlock that will occur between any two moisture conditions. For example, suppose a builder desires to know how much a subfloor of 6-inch flat-sawn western hemlock boards at 20 per cent moisture content will shrink when the boards come to about 6 per cent moisture content, as they probably will in a heated building. A line through 6 per cent moisture content on the left side of Figure 17 meets the tangential shrinkage curve at 6.3 per cent average shrinkage. (See dotted line on fig. 17.) A line drawn similarly through 20 per cent meets the tangential shrinkage curve at 2.6 per cent. The difference between the two values obtained is 3.7 per cent average shrinkage. The average board under the foregoing conditions will, therefore, shrink 3.7 per cent of 6 inches or about one-fifth of an inch, leaving cracks this wide between boards originally laid tight. The openings in such a floor 20 feet wide would total about 9 inches, and the floor might be unsatisfactory, not because it was built of western hemlock, but because the wood was not properly seasoned when laid.

ABILITY TO STAY IN PLACE

The ability of a wood to retain its size and shape in use depends partly upon the amount, rate, and manner in which it shrinks and partly upon the amount of cross grain present. Shrinkage and straightness of grain, however, do not entirely account for the differences among species in this respect, and a numerical comparison of western hemlock with other species in ability to stay in place is not possible because of the unknown factors and because no comparative figures are available on straightness of grain. A general comparison based on the best available shrinkage data and observation indicates that western hemlock stays in place about as well as Sitka spruce, somewhat better than Douglas fir and western larch, but not so well as northern white pine, western yellow pine, and chestnut.

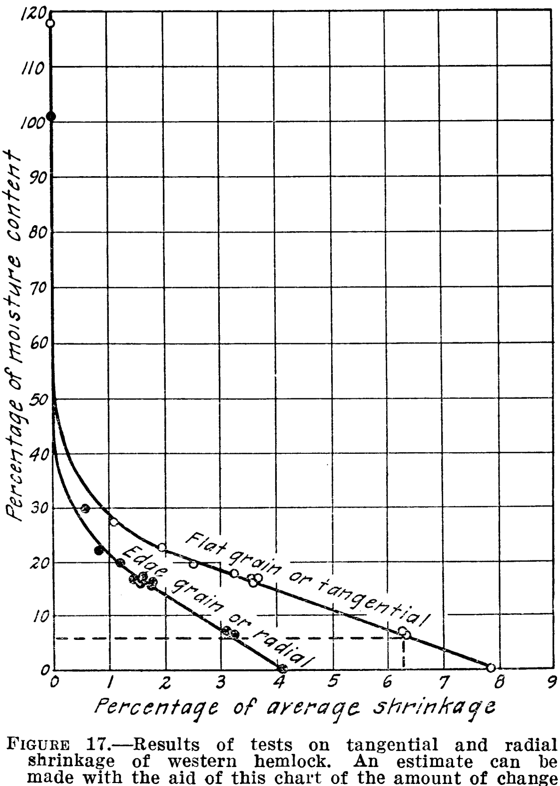
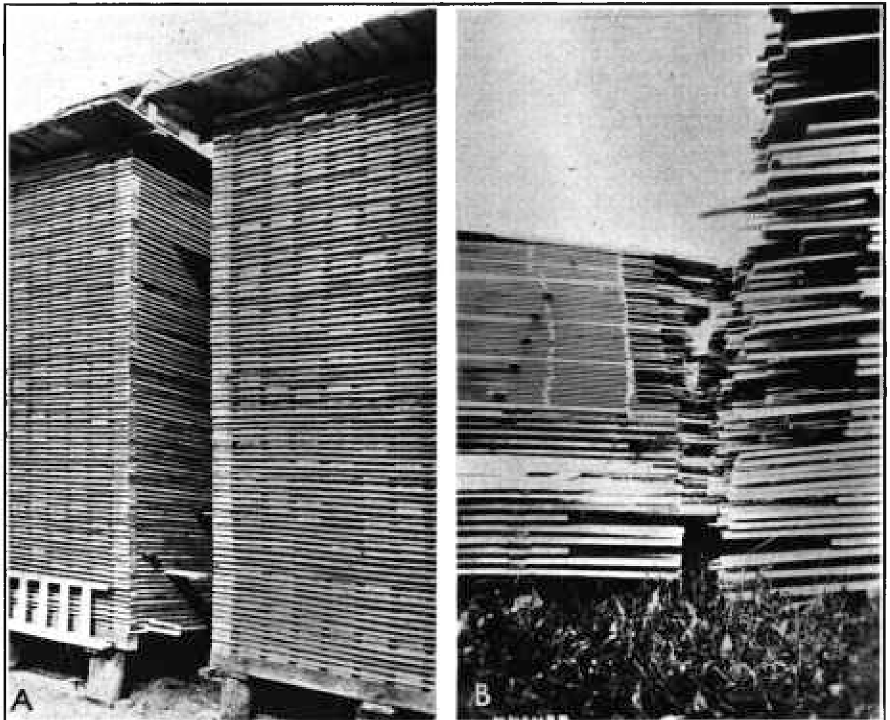


FIGURE 17.—Results of tests on tangential and radial shrinkage of western hemlock. An estimate can be made with the aid of this chart of the amount of change in dimension that will take place with changes in the moisture content of the wood

A large number of uses, such as interior trim, flooring, and siding, require along with other properties that the wood must stay in place moderately well. The properties and reputation of western hemlock indicate that it can satisfactorily meet the requirements of such uses in this respect, provided it is properly seasoned. On the other hand, for uses such as in patterns where ability to stay in place is of major importance the soft pines are better.

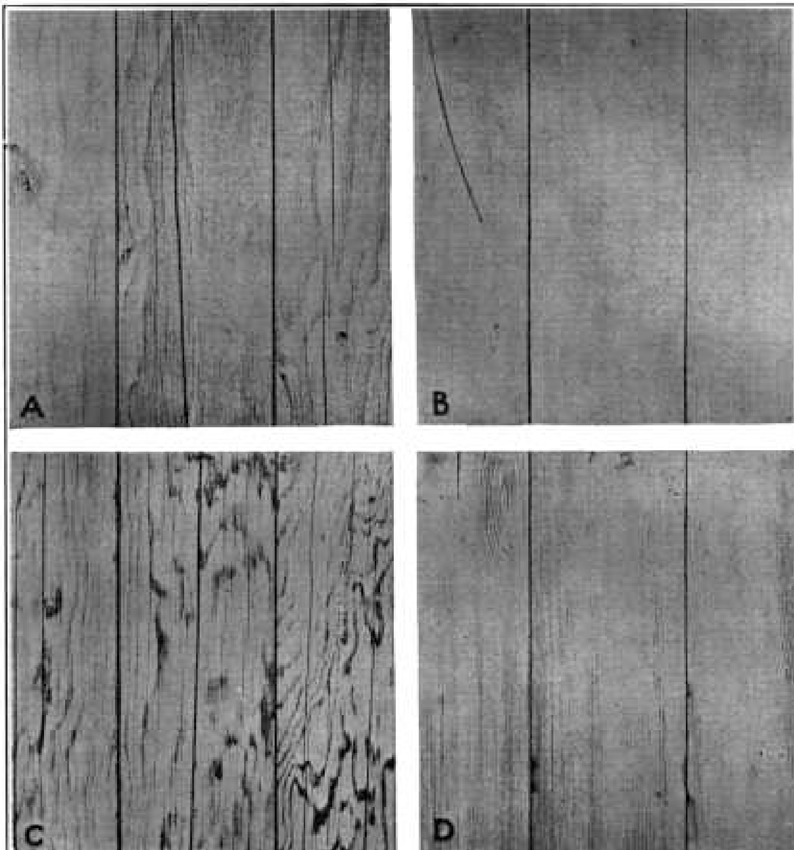
SEASONING

Both the air drying and kiln drying of western hemlock are comparatively easy to accomplish without heavy losses or degrade.



GOOD AND POOR SEASONING PRACTICE

A.—Pile foundations are in units, piling is good, and yard is sanitary.
B.—There are not sufficient foundation stringers, the overhang is excessive, the stickering is uneven, and the condition under piles is unsanitary. Warped boards often result from such conditions.



EXPERIMENTAL PAINT PANELS AFTER 2½ YEARS' EXPOSURE UNDER SEVERE CONDITIONS AT MADISON, WIS.

A and B.—Western hemlock panels: A, Flat grain. Western hemlock panel showing less paint flaking from the summer wood than C, a comparahle panel of a more coarsely textured wood with same kind of paint of the same age. Weather checking of the wood, due to inadequate protection by the coating at this stage in its life, is much worse than on B; B, edge grain. Edge-grained western hemlock holds paint much hetter than flat-grained. The panel is in excellent condition and compares favorahly with species of wood which rank high in paint-holding capacity.

C and D.—Softwood panels which have more pronounced summer-wood bands than western hemlock: C, Flat grain. Characteristic failure of paint over summer-wood hands; D, edge grain. The edge-grained panel of softwood with alternate hands of hard and soft wood is in hetter condition than the flat-grained panel, hut disintegration of paint over summer-wood hands is shown.

The wood is relatively free from the more serious drying difficulties such as staining, warping, collapse, and honeycombing. Most of the difficulties and part of the time required to dry western hemlock are the result of its comparatively high moisture content when green, together with the wide variation in the moisture content of individual pieces. In spite of its high initial moisture content it is easier and quicker to dry than redwood or cypress, but slower than Douglas fir and Sitka spruce. On the other hand Douglas fir appears to be more subject to surface checking than western hemlock. In kiln drying western hemlock some trouble has been experienced with kiln browning, which discolors both the heartwood and sapwood. Laboratory tests indicate that superheated-steam treatments may cause kiln browning in both western hemlock and sugar pine.

Proper seasoning can be obtained either by air drying (*13*, *15*) or kiln drying (*23*). The present general practice with western hemlock is to kiln dry all of the select stock direct from the saw, whereas practically all of the common stock is air seasoned or shipped green. Lumber for box shooks is practically all air dried regardless of whether the shooks are to be shipped by rail or water.

Plate 7 illustrates examples of good and poor air-drying conditions. Plate 7, A, shows good foundations, well-piled lumber, and sanitary yard conditions in contrast to those shown in Plate 7, B. Poor air-drying conditions result in much degrade due to the warping and twisting of the boards.

Kiln-drying schedules (*23*), which experiments have shown will dry select grades of western hemlock without excessive degrade, are given in Table 3. It may be possible to dry the species with severer schedules than those recommended, but such schedules require more care and judgment on the part of the kiln operator. Even the treatments recommended will probably result in slight injury to the strength as compared with that which would result from milder kiln conditions or from air drying. If western hemlock is to be dried for specialty uses, where maximum strength is desired, such as in ladder stock, the temperatures and humidities of Aircraft Schedule 101 of the Kiln Drying Handbook (*23*) should not be exceeded.

TABLE 3.—*Kiln-drying schedules for western hemlock*

Thickness of stock	Moisture content at which change should be made, (per cent)	Drying conditions		
		Maximum dry-bulb temperature	Wet-bulb temperature	Minimum relative humidity
		° *F.*	° *F.*	*Per cent*
4/4 to 6/4	45 or more	180	165	70
	40	190	161	50
	20	200	150	30
7/4 to 9/4	40 or more	180	165	70
	35	190	161	50
	16	200	150	30
10/4 to 12/4	35 or more	135	123	70
	30	150	126	50
	20	165	132	40
	15	175	130	30

EASE OF MACHINING AND WORKING

Ease of working with hand and machine tools, both as to character of surface obtained and work involved, is more dependent upon the character and condition of the cutting edges than on the species. Thus dull or unsuitable tools, improper bevels, setting or speed of machine knives, and improper seasoning may lose for western hemlock, or any other species, such advantages as it may have in ease and smoothness of working. The necessity of considering the kind and the condition of tools used complicates the comparison of species of wood for workability, and at the present time no satisfactory numerical method of measuring workability has been devised. The comparisons given between western hemlock and other species are, therefore, general and are drawn from observation, experience, and a study of such properties as hardness and texture, which have an influence on the ease of working.

The absence of resin, gum, and mineral substances in western hemlock and its uniform texture, moderate softness, and straightness of grain make it easy to cut, turn, and shape. In this respect it is in general somewhat easier to work than Douglas fir or southern yellow pine and is somewhat similar to southern cypress, and white fir, but is not so easy to work as northern white pine, western white pine, or western yellow pine.

When western hemlock is planed or joined, the finished surface is not so smooth as that of some of the pines, especially western yellow pine, in that the finished surface lacks the slick polished appearance of these species. Also in crosscutting, the edges are not so clean cut and smooth because western hemlock has a greater tendency to break back from the edge, especially with dull or coarse saws. On the other hand, western hemlock does not fuzz so much as white fir and the grain does not raise so much as in Douglas fir or the southern pines.

NAIL-HOLDING CAPACITY

Western hemlock when nailed in a dry condition holds nails about as well as Douglas fir (coast type), slightly better than western white pine, and considerably better than western yellow pine and white fir, but not so well as southern yellow pine. This comparison takes no consideration of the tendency of wood to split in nailing, but refers only to the inherent holding power of the wood itself. A comparison of the nail-holding power of western hemlock with these and other species is shown in Figure 18. The comparisons in Figure 18 are based on tests made with 7-penny cement-coated nails. Other tests, however, indicate that if tests were made using other sizes and types of nails the results would be substantially proportionate.

The nail-holding power of wood is generally proportional to its specific gravity. Woods that have a higher specific gravity than western hemlock, therefore, usually have a higher nail-holding power. This rule affords a means of roughly comparing western hemlock with species not shown in Figure 18.

Western hemlock when nailed in a green condition has a comparatively high nail-holding power as long as the wood remains wet. If, however, the wood dries after nailing, the nails rapidly lose their grip in the wood, so that by the time the wood is air dried to about 12 per cent moisture content the nails retain only about one-fifth of the holding power they had when first driven into the green wood. The loss of nail-holding power with drying is exceptionally high in western hemlock, being about equal to that in white fir and greater than that in eastern hemlock, northern white pine, western yellow pine, and western larch. (Fig. 19.) It is poor practice to nail into green wood of any species when the wood will later dry out in use, and it is especially poor practice in western hemlock.

Nail-holding power is of importance in studding and other framing material used in construction, and especially in box material since the nailing is the weakest point in the wooden box.

SPLITTING

Resistance to splitting is commonly measured by cleavage tests and by tension tests in which blocks of standard size and shape are

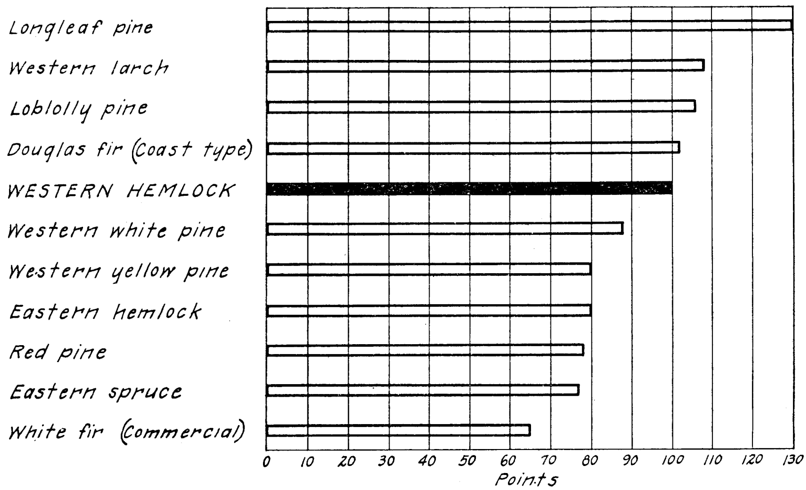


FIGURE 18.—Results of tests on holding power of nails driven into and pulled at once from dry, clear wood of western hemlock compared with that of other species of wood. Western hemlock taken as 100 points. Comparison based on tests made with 7d cement-coated nails pulled from wood unaffected by shakes, checks, and other defects. Nail-holding power is an important requirement in wood used for boxes, joists, roofing boards, and in similar uses

pulled apart by forces acting at right angles to the grain. The results of such tests are shown in Figure 20. The value of hemlock is taken as 100. Cleavage and tension tests, however, do not show the tendency of a wood to split in handling or in service, neither do they indicate the relative likelihood of splitting in nailing. Splitting under the action of nails is influenced by hardness, straightness of grain, and evenness of texture, as well as by ability to resist tension across the grain. If two woods have equal tension values, other things being equal, they will have about the same percentage of split pieces in nailing. If, however, the two woods have equal tension values but differ in hardness, then it will require more force to drive nails in the harder wood, and greater splitting action will be exerted. The harder wood will, therefore, split more often in nailing. The hard summer-wood bands in wood of nonuniform texture cause nails to turn and split the wood, while cross grain causes splitting at the edges of the piece.

A comparison of western hemlock with other species of wood in respect to inherent resistance to splitting as measured by cleavage and tension tests shows western hemlock to have about the same splitting resistance as Douglas fir, a higher resistance than eastern hemlock, and a lower resistance than southern yellow pine and western yellow pine. A comparison of the tendency of these species to split in nailing, however, as indicated by an analysis of the effect of such properties as hardness, texture, and grain, in combination with splitting resistance in tension, shows quite different results. Douglas fir has about the same tension-splitting resistance as western hemlock, but because Douglas fir is harder, less uniform in texture, and more subject to cross grain than western hemlock it splits more

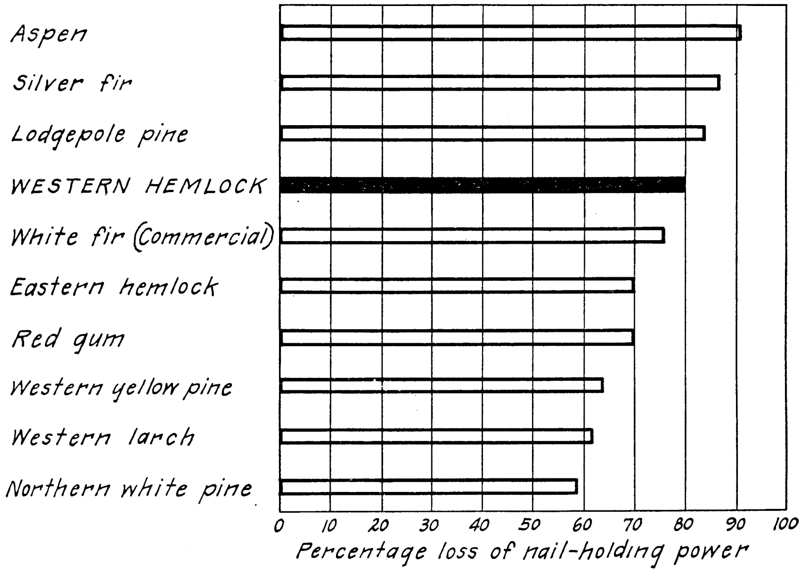


FIGURE 19.—Results of tests on loss of nail-holding power of western hemlock as compared with that of other species of wood, when the wood is nailed in a green condition and then seasoned. This loss is so large that the moisture condition of the wood at the time of use is often more important than the species of wood used.

often in nailing. Southern pine likewise will split more in nailing than western hemlock, even though it has a higher resistance to tension splitting, because of its greater hardness and more pronounced bands of summer wood. Eastern hemlock will also split more in nailing than western hemlock, although its hardness is about the same, because it is lower in tension-splitting resistance and has more shake. Western yellow pine, on the other hand, will split less in nailing than western hemlock because it is softer, more uniform in texture, and has a higher tension-splitting resistance.

A comparison of the splitting to be expected in yarding, handling, and service is not so readily made, for additional factors, such as seasoning and manufacturing, influence the amount of such splitting. If, however, the consumer is familiar with the conditions in which the different species of wood come on his local market, he can use the splitting resistance as a basis for a comparison similar to the one made for nailing. Thus, if two species of wood have about the same splitting resistance, but one is coming on the local market checked and cupped more than the other, the checked and cupped material is likely to split more in handling and in service. Of two species differing in splitting resistance, the one with the greater amount of seasoning defect will generally split more in handling and service than the other even though it is the higher in splitting resistance.

GLUING QUALITIES

Laboratory tests (*24*) indicate that with western hemlock satisfactory glue joints can readily be obtained with animal, vegetable, or casein glue. (Fig. 21.) Western hemlock, on account of its good gluing characteristics may be used where wood is glued under ad-

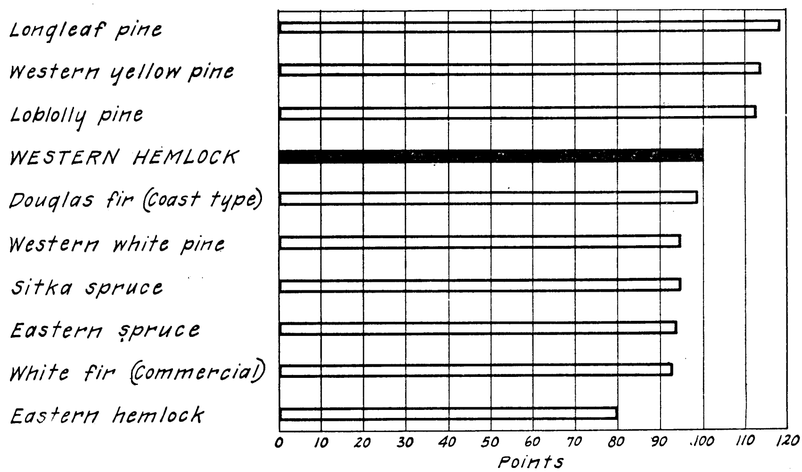


FIGURE 20.—Results of tests on the splitting resistance of clear wood of western hemlock compared with that of other species of wood. This comparison is based on wood free from shakes, checks, and other defects. The tests were made by pulling apart small blocks across the grain. The results do not indicate the tendency of the various woods to split in nailing

verse conditions, where the cost of carefully controlled gluing conditions is not justified, and where gluing is performed by relatively inexperienced persons.

PAINTING AND FINISHING QUALITIES

Western hemlock holds the customary base paints reasonably well as compared with other woods. The knots, which in many woods are a cause of early paint flaking, in western hemlock hold paint almost as well as the clear wood, so that in the lumber grades below B and Better, western hemlock ranks particularly high among woods in capacity to take and hold paint. Smooth interior paint and enamel coatings applied to wood reasonably free from raised grain may ordinarily be obtained on flat-grained boards of western hemlock. Neither the heartwood nor the sapwood of western hemlock contains resinous material that will discolor paints or enamels. On exterior exposure, paint fails eventually on flat-grained surfaces of western hemlock by flaking from the summer wood, but this does not occur so soon as it does on woods having denser summer wood disposed in wider bands. (Pl. 8.) On western hemlock many paints fail because of weather checking of the wood before much, if any, wood surface has been left bare through flaking from the summer wood. (Pl. 8, A.) Edge-grained boards of western hemlock hold paint better and require less paint protection to prevent weather checking than do flat-grained boards. (Pl. 8, A and B.) When flat-grained boards are used, especially out of doors, they should be placed with the sap side rather than the heart side exposed to the

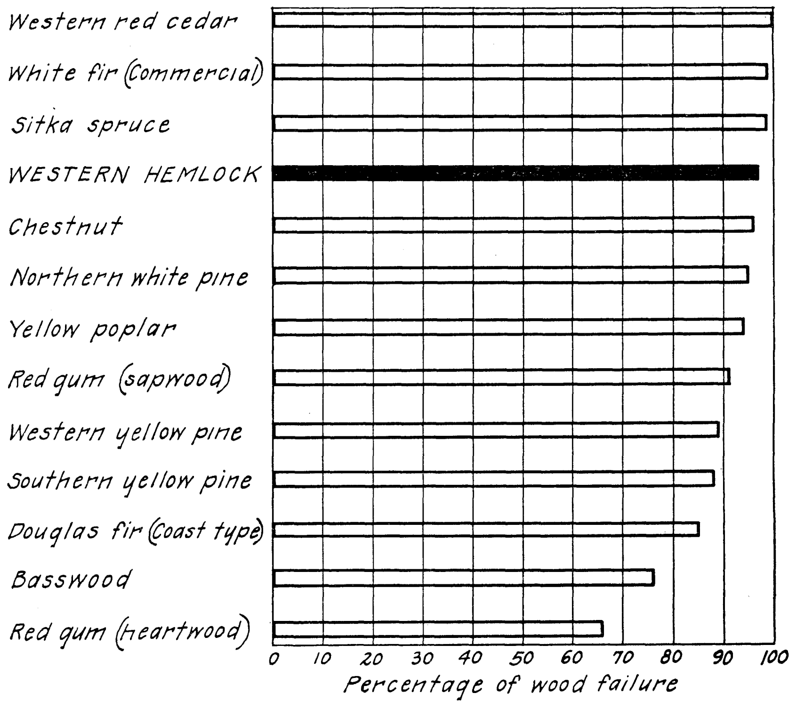


FIGURE 21.—Results of tests on gluing qualities of western hemlock as compared with other species of wood. Joints made with animal, vegetable, and casein glues. The smaller the percentage of wood failure the greater the care required to obtain satisfactory glue joints. Percentage of wood failure, however, is not a direct measure of percentage of the strength of wood developed by glued joints

weather in order to prevent the possible development of loose grain in spite of paint protection.

A study of the painting characteristics of western hemlock and 16 other woods when painted with paints and by methods representative of customary practice in house painting has been in progress since 1924, (*8*, *9*). The following comparisons of western hemlock with other species of wood are based on the results obtained from 11 experimental fences located at widely separated points throughout the United States. In these tests, which were all in exterior exposure, western hemlock did not hold paint so well as southern cypress or the cedars and not quite so well as northern white pine, western white pine, or sugar pine. Its holding capacity was very similar to that of eastern hemlock and the spruces. It was slower than Douglas fir, southern yellow pine, western larch, and white fir in yielding to the tendency for paint to flake from its bands of summer wood, just as would be expected from the fact that western hemlock is more uniform in texture than these woods and its summer wood apparently is lighter and generally in narrower bands. The knots in western hemlock held paint as well as the knots in any other commercial softwood species of wood, no doubt because of their nonresinous nature.

No similar investigation has been made of the painting characteristics of woods for interior exposure. Since in such uses paint flaking from summer wood on aging is not normally experienced, the result of outdoor tests are not immediately applicable to indoor conditions. However, in general, woods of uniform texture, with light summer wood, are preferred for smooth paint and enamel finishes. Western hemlock on that score takes the rating among the softwoods given in the preceding paragraph. In addition it is free from the tendency for the paint or enamel to turn brown over the heartwood.

No experiments have been conducted by the Forest Service for determining the qualities of different species of wood with respect to varnishing and natural finishing. The deciding factor in the selection of species for natural or varnish finish, however, is usually the lüster of the wood and the character and beauty of the figure. Western hemlock is often used for purposes which require such finishes. When a natural finish is used on western hemlock it quite often has light and dark areas, which give a dappled effect somewhat similar to that shown by natural-finished curly birch. The effect may be desirable or undesirable depending on the individual taste and the general effect desired. Where it is not desired it can be modified by using a thin coat of shellac as a filler before applying a stain.

RESISTANCE TO DECAY, WEATHERING, AND INSECTS

In general, western hemlock is not suited for use under conditions that are favorable to the growth of wood-destroying fungi, unless it has received a good preservative treatment.

Comparisons of the relative decay resistance of untreated western hemlock and different species must be estimates. They can not be exact, and they may be very misleading if considered as mathematically accurate and applicable to all cases. They may be very useful, however, if considered as approximate averages only, from which specific cases may vary considerably, and as having application only where the wood is used under conditions that favor decay.

Service records where available, supplemented by general experience, lead to the classification of the heartwood of the cedars, chestnut, southern cypress, the junipers, black locust, red mulberry, Osage orange, redwood, black walnut, and Pacific yew as much more durable than western hemlock.

Similarly the heartwood of aspen, basswood, cottonwood, the true firs (not Douglas fir), and the willows may be classed as lower in decay resistance than western hemlock, while the heartwood of Douglas fir, red gum, western larch, chestnut oak, southern yellow pine, and tamarack may be classed as slightly more durable than western hemlock. The heartwood of dense Douglas fir, honey locust, white oak, and dense southern yellow pine may also be classed as considerably more durable than western hemlock, while the ashes, beech, the birches, sugar maple, the red oaks, and the spruces may be considered as having the same decay resistance as western hemlock.

Untreated western hemlock crossties have been estimated to have an average life in service of from five to six years, as compared to six to seven years for Douglas fir crossties and three to four years for white fir crossties; this estimate, however, is only approximate because the decay resistance will vary widely with the moisture conditions of service and with the percentage of sapwood, since dampness favors the growth of the fungi that destroy wood and the sapwood of all species will usually rot quickly under conditions that favor decay.

The weathering of flat-grained western hemlock, which is caused by unequal drying when exposed to the weather, especially when unpainted, is characterized by relatively little grain rising and by a comparatively few long checks rather than numerous short ones. Edge-grained western hemlock weathers well, the characteristic checks of the flat-grained material being absent, as is the washboard effect from unequal weathering of spring wood and summer wood. This description of the weathering characteristics of western hemlock is based largely on results from unpainted panels exposed for two and one-half years at Madison, Wis., and to a less extent on painted panels exposed in various parts of the United States.

A comparison of the weathering of western hemlock and the weathering of other species based on these same panels indicates that flat-grained western hemlock weathers less than flat-grained Douglas fir or eastern hemlock. The weathering of flat-grained western hemlock is confined largely to checking and cupping. In the other species mentioned the checking and cupping are at least as severe as in western hemlock, and in addition the grain rises. Flat-grained southern cypress and the cedars weather less than flat-grained western hemlock because they check less. In edge-grained material there is little difference between these species and western hemlock.

All native species of wood are subject to attack by termites, or white ants, and vary only slightly in susceptibility. Western hemlock, however, does not rank high in resistance to attack by termites, and if it is used under conditions that favor their attack the customary precautions (*20*) should be observed.

PRESERVATIVE TREATMENT

Preservative treatment largely eliminates the difference in the decay resistance of species of wood. Given a good preservative treatment, therefore, western hemlock, like other species, will have entirely satisfactory decay resistance. Preservative treatments broaden the field of usefulness of western hemlock by enabling it to be safely and satisfactorily used under conditions that favor rapid decay.

The available information on the treating characteristics of western hemlock is not sufficient to permit a comparison with other species of wood. It is known, however, that western hemlock can be treated successfully with creosote or water-soluble preservatives by standard methods and that the treatment of the species with these preservatives presents no serious problems.

HEAT AND INSULATING PROPERTIES

Although no tests have been made on the heat conductivity of western hemlock, tests on other species of wood indicate that the denser or heavier the wood the greater is its heat conductivity (*6*, *30*). Western hemlock would therefore be expected to have a higher insulating value than Douglas fir, southern yellow pine, or southern cypress, and about the same as Sitka spruce, northern white pine, western white pine, or eastern hemlock, and lower than western red cedar.

All woods have high heat-insulating properties, and the differences in heat conductivity among species are small as compared with other factors affecting heating loss (*19*).

PERMEABILITY BY LIQUIDS

Western hemlock does not appear to be particularly easy to penetrate with liquids. General observation on the penetration of wood by liquids indicates that when leakage occurs from tight cooperage of western hemlock it is due to some cause other than the ease with which the liquid penetrates the wood itself. There are not sufficient data to prove or disprove the common belief that western hemlock absorbs liquids quickly and to such an extent that most liquids will leak or seep from containers made from it.

TENDENCY TO IMPART ODOR OR FLAVOR

The substance which causes western hemlock to have a sour odor while green is apparently changed chemically in drying, because once dried western hemlock loses its odor. Even when dry western hemlock was soaked, no return of the disagreeable odor of the green wood could be detected in a series of trials conducted at the Forest Products Laboratory. These trials are substantiated by tests made by the Bureau of Animal Industry[12] and by the fact that western hemlock is used for butter containers without any record of detriment to their contents.

TENDENCY TO LEACH COLORING MATTER

Western hemlock wood has no gums, oils, or water solubles that leach out and discolor foods, paints, plaster, or corrode metals. The bark, however, contains a relatively high percentage of tannin, and this will leach out and color some substances, such as plaster, when it comes in contact with them. For uses such as lath, where staining from leached tannin is objectionable, a grade which prohibits bark should be used.

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[12] UNITED STATES DEPARTMENT OF AGRICULTURE, BUREAU OF ANIMAL INDUSTRY. INVESTIGATION OF THE SUITABILITY OF VARIOUS KINDS OF WOOD FOR BUTTER CONTAINERS. . . . U. S. Dept. Agr., Bur. Anim. Indus. 1919. (Unpublished report.)

CHEMICAL PROPERTIES

An experiment on western hemlock made at the Forest Products Laboratory gave a yield of 23 gallons of ethyl alcohol per ton of wood, 21 per cent of the wood being convertible into sugars and 77 per cent of these sugars being fermentable (*26*). This yield was about 10 per cent higher than was obtained from Douglas fir, about 12 per cent lower than was obtained from white spruce, and about double that obtained from any of the hardwoods.

It is reported that no chemical reactions that are detrimental to the sheathing of lead-covered cables take place when creosoted western hemlock is used for buried conduits that have no ventilation (*11*).

ACID AND FIRE RESISTANCE

There are no data available on the acid-resistance qualities of western hemlock, but from the fact that the only known species with high acid resistance are those with high decay resistance, it is not likely that western hemlock will rank high in resistance to acids; at least on the basis of present knowledge it can not be recommended for uses requiring this property.

The data on the inflammability of western hemlock are not sufficient to justify any but a very general comparison with other species of wood, because the observed difference in the inflammability of species is too small to be significant in view of the wide variation observed in individual pieces of the same species. While western hemlock will burn readily, it will not ignite so easily as resinous woods.

Laboratory tests have shown that western hemlock bark has a tannin content (*1*, *7*) that usually runs from 12 to 15 per cent, whereas eastern hemlock bark usually has from 10 to 12 per cent tannin.

USES OF WESTERN HEMLOCK

In comparison with other commercial softwoods western hemlock is in a middle position with respect to most of its mechanical properties, and is therefore used for a wide range of purposes. The properties that make it suitable for interior trim, siding, flooring, boxes, ladders, and core stock are high strength for unit weight; good painting and gluing characteristics; light, bright color; lack of gums and resins; fairly uniform texture; and workability. On the other hand, low resistance to decay precludes its use untreated in contact with the ground or in moist or damp locations such as that of flooring in stock barns or decking in freight cars. It is evident, therefore, that while western hemlock is suitable for a wide range of uses, its low resistance to decay does not fully warrant lumber yards carrying it as a single species to supply the widest variety of uses.

THE RELATION OF PROPERTIES TO USES

In determining the value of western hemlock or any other kind of lumber for any specified use, consideration should be given to the relation of its properties to the requirements most essential for that use. This fact, self-evident though it appears, is not universally regarded nor is it easy to apply practically. The determination of the most essential requirements for a use may sometimes necessitate considerable study and exacting research. In addition, as previously pointed out, the value of a species of wood for a given use is ordinarily based upon a combination of properties rather than upon a single property. While the relative importance of the properties is undetermined in most uses, the consumer in his daily contact with his particular use may observe and study the essential requirements and compare these requirements with the properties of western hemlock. Thus he can arrive at a conclusion as to the suitability of western hemlock for his purpose.

The discussion of the uses of western hemlock is intended to show how the properties apply to some of th emore important uses. In the absence of laboratory or service tests, the requirements of a use are based upon observation and experience. The discussion of the uses should therefore be considered in the nature of illustrations intended as an aid or guide to the use of the information on properties of western hemlock, rather than as a specific recommendation or final conclusion resulting from scientific tests.

GENERAL BUILDING MATERIAL

The most important and largest use of western hemlock is as a building material. The term building material, however, includes a number of specific uses, and western hemlock, like most softwoods, is manufactured into a number of items, such as boards, ship-lap, dimension, flooring, and finish, largely to meet the various requirements of the building trade. Some of these items, such as boards and dimension, are used for several purposes, while other items, such as siding and flooring, have more restricted uses. Hence any general discussion of western hemlock for so varied a use as building material would be too indefinite to be of much value. The various items of western hemlock yard lumber are, therefore, discussed as to suitability for specific uses in buildings.

COMMON BOARDS AND SHIP-LAP

Common boards are a lumber item that is not manufactured for any specific use. The mill operator, at the time of sawing, does not know into which of the many uses this class of product will go. The yard dealer, when common boards and ship-lap leave his yard, may or may not know the use to which they are to be put. Certain consumers even require a general-utility board.

Western hemlock has several characteristics which are favorable to its general use as boards and ship-lap. It has a uniform texture and moderate softness, which make it easy to saw and nail; lightness, which makes it easy to handle; and knots that are relatively small and tight in all grades. The character of the knots and freedom from resin and pitch pockets contribute to its good painting qualities. Taken with its light, bright color and lack of sap stain, these characteristics in western hemlock appeal to the consumer on the basis of appearance even for strictly utilitarian purposes. On the other hand, its relatively low decay resistance is a drawback where it comes in contact with the ground or is exposed to moist conditions.

To the extent that the final use can not be anticipated, western hemlock boards and ship-lap are not to be classed with the stronger and more decay resistant species of wood. However, where the final use can be determined at the time of purchase, the common boards of western hemlock have a large field of usefulness. This field of usefulness will be realized only as purchases can be linked more closely with specific uses.

The requirements of the individual uses to which common boards are put in building construction warrant separate discussion with reference to the suitability of western hemlock.

SUBFLOORS

The principal species of wood used commercially have sufficient strength for use as subflooring. Standard methods of construction are such that there is little or no danger of subfloors failing mechanically. Where western hemlock is used, it is usually because of its moderate softness, uniform texture, and lightness, which make it easy to put in place; also because of its straightness of grain, combined with moderate shrinkage, which tend to reduce warping and twisting both before and after laying; and because of its relatively small tight knots, which not only give a tight floor but present a good appearance during construction. All of these points are of such a nature that they may be largely offset by insufficient or poor seasoning.

There is, however, little difference in the suitability of western hemlock and other species of wood for subfloors. The individual user must choose between strength on the one hand and ease of working combined with good appearance and lack of warping on the other.

SHEATHING

The principal purposes of sheathing are to tie various parts of a structure into units and to prevent the passage of air into and out of the structure. Differences in strength and decay resistance of different species of wood have little practical significance for this use. Even small differences in the type of construction will more than offset the differences in the strength and stiffness of any of the species of wood commonly used for sheathing. For example, walls braced or diagonally sheathed with lumber of relatively low stiffness will be stiffer and stronger than unbraced walls or walls horizontally sheathed with a stiffer species of wood. Even a difference in the method of nailing horizontal sheathing may offset differences in the stiffness of the lumber used. Again, where western hemlock is used for sheathing it is usually because of ease of sawing and nailing, small tendency to warp and twist, and tightness. The result is that the choice of a species of wood for sheathing depends largely on price, grade, and the thoroughness of seasoning.

ROOF SHEATHING

Several properties are desired in wood used for roofing boards. The wood should have good nail-holding power in order to hold shingles or other roofing; it should not split excessively where roofing nails come through; and it should have sufficient stiffness so that the boards do not spring too much under the hammer, making the driving of nails difficult and tending to cause overdriving and splitting of shingles. Lightness, which facilitates ease of handling to and on the roof, is also desirable. A comparison of western hemlock with other species for the properties mentioned is made under the heading "Mechanical and Physical Properties." The relative importance of the different properties is a matter of judgment. The final selection of a species of wood will therefore vary, depending upon the importance the consumer assigns to the various properties.

Although a few species of softwood now furnish the bulk of the roofing boards, western hemlock is one of several other species of wood that can be used satisfactorily, particularly if the wood is properly seasoned when put in place. Generally a comparison of western hemlock with the principal species now used for roof sheathing will show that it splits less under shingle nails than some species of wood commonly used and has about the same nail-holding power. It is also lighter but nevertheless stiffer for its weight. Against this must be balanced its actual moderate stiffness. Its low decay resistance may also become a disadvantage in case leaks develop in the roof.

CONCRETE FORMS

Wood in concrete forms is subjected to very severe conditions. The boards, alternately wet and dry, must support heavy loads of wet concrete, and resist rough handling when taken down. Wetting on the inside and drying on the outside furnish exactly the right condition to cause boards to warp, check, or split, which often prevents some of the boards being reused for forms. Checking and splitting have a good chance to develop further under the force usually applied in taking down the forms. A discussion of tendency to split in service is given on page 31, and a comparison of the splitting resistance of western hemlock and other species of wood is shown in Figure 20.

Western hemlock is often used for concrete forms because of the characteristic small size and tight character of its knots. The size and character of the knots are quite often given more consideration in the selection of concrete form material than the strength properties. The strength in bending (fig. 11) and stiffness (fig. 15) of material for concrete forms should, however, be considered. The relative importance of the defects and the strength and stiffness depend upon the type and character of the forms.

MISCELLANEOUS FARM USES

For use in the construction of barns and other farm buildings, western hemlock boards and ship-lap have a number of properties which commend them. On the other hand, for general use about the farm or as stock material for all types of repairs, decay resistance and strength become desirable and, therefore, the more decay-resistant and stronger species of wood are preferable.

The characteristics of western hemlock boards that are important to farm use are the good painting characteristics, light weight, uniform texture, and moderate softness, which make the boards easy to work and handle. Good painting characteristics are desirable in that many barns and outhouses are painted. Moderate softness and uniform texture are desired because the farmer must do his cutting and shaping with more limited and often poorer tools than the carpenter or contractor uses. In addition, the farmer may have to do most of the handling alone, which makes lightness generally desirable. The characteristic small tight knots, the slight tendency to warp or twist; and the freedom from hard summer-wood bands which deflect nails make western hemlock common boards desirable for farm use inasmuch as these factors insure tight buildings. Unpainted western hemlock boards do not sliver or show raised grain as much as species of wood with pronounced alternate bands of hard and soft wood.

For many uses, such as the lower floors of barns, coops, and pens, and for wooden walks, the decay-resisting or strength properties, or both, make western hemlock less desirable than stronger and more decay-resistant species of wood. In fact, some conditions are so favorable to decay as to prohibit the use of western hemlock unless treated with a preservative. Untreated western hemlock can not, therefore, be used for all miscellaneous farm uses, but can be used to advantage where resistance to decay is not essential.

SHELVING

Shelving should lie flat and not rock on its supports. It should not sag excessively under the load it is required to carry, and it should hold the paint film well. Western hemlock boards, because of their straight grain and moderate shrinkage (fig. 16), may be expected to lie flat. Their stiffness (fig. 15) is such that with the short span commonly used sagging will not be objectionable. They take and hold paint well. Much shelving contains knots; however, the nonresinous character of the knots in western hemlock gives it a distinct advantage over woods with pitchy knots in that the paint over them does not discolor or peel. A comparison of the painting characteristics of western hemlock and some other species of wood used for shelving is made on page 34.

DIMENSION STOCK

Although western hemlock dimension stock has the same properties as western hemlock boards, the importance of the properties differ considerably with different uses. Thus, stiffness, breaking strength, and nail-holding power are usually more important in dimension than in boards, while tightness of knots, painting or gluing characteristics, and appearance are less important.

A large proportion of the western hemlock cut goes into dimension stock. The thickness of most of it is 2 inches rough green (dressed to 1⅝ inches), although some 3 and 4 inch rough green (dressed to 2⅝ and 3⅝ inches) is manufactured. The widths vary from nominal 4-inch actual 3⅝-inch, to nominal 12-inch, actual 11½-inch. While more 2 by 4 inch stock is cut than any other size, 10 and 12 inch widths in lengths of 16 feet and longer, in multiples of 2 feet, are readily available.

Western hemlock dimension is low in weight for its stiffness, a desirable characteristic where the cost of shipping or handling must be considered. It combines uniform texture and moderate softness, making it easy to shape, saw, or nail. It has good nail-holding power when dry, which is a desirable property in framing material. On the other hand, in both bending and compressive strength, western hemlock more nearly resembles the weaker than the stronger of the softwood species that are used extensively in dimension grades and sizes.

JOISTS AND STUDDING

Stiffness is desired in joists and studs because of its influence upon the rigidity of floors and walls. A comparison of the stiffness of western hemlock and a number of the species of wood commonly used for framing is made in Figure 15. Stiffness values, for use in computing the average deflection of stringers, joists, rafters, and other structural parts, are shown in the last column of Table 1. Actual rather than nominal sizes must be used in these computations. In structures where it is desired to prevent sag, which takes place under continued loads of about 10 years, values one-half of those shown in the table should be used since both deflection and permanent sag occur under long-continued loads. The stiffness values in the table are applicable to all grades, since defects, except decay, have little if any injurious effect upon stiffness. Grades that permit knots and other defects and exclude decayed material may be used where stiffness is the controlling factor, since material of such grades, even though its breaking strength is materially influenced by the defects, still has sufficient strength to carry safely the loads likely to be placed upon it. Knotty material, because of the cross grain around the knots, however, has a somewhat greater tendency to warp or twist than does clear material. In so far as stiffness is concerned, therefore, differences in grade are of little importance in the selection of most joists and studding, provided the grades are equally well manufactured and seasoned.

Ease of working and lightness, which makes handling easier, are the properties of western hemlock joists and studs that appeal to contractors and carpenters. The home owner, however, is only interested in the influence of these properties on his labor costs. In the choice of a species of wood, therefore, he should balance the greater stiffness of the heavier, stiffer, and harder-to-work species against the saving in labor costs possible with the lighter and easier-to-work western hemlock.

The difference in the nail-holding properties of western hemlock and other species of wood commonly used for joists and studding is not great (fig. 18), provided the material is properly seasoned. Good nail holding is desired in joists because failure of nails to hold results in squeaky floors. Failure of nails to hold in studding causes loose sheathing and siding. The moisture condition of the wood at the time of nailing, however, is more likely to be responsible for squeaking floors and openings that permit the passage of air through walls than the species of wood used in the joists or studding.

In house construction, bending strength and resistance to decay are of secondary importance in joists and studs. The sizes required to give requisite stiffness in grades normally used have sufficient strength to carry much heavier loads than are likely to come on them. Joists in houses, therefore, seldom break. In the common types of construction, joists and studs are usually dry, well ventilated, and protected from exposure to water. Under these conditions decay organisms can not carry on their destructive work, and western hemlock will therefore last as long as the more decay-resistant species of wood.

Occasionally, however, the bending strength of joists displaces stiffness as the most important factor, as in warehouse floors, which carry heavy loads and have no plaster under them to crack. For such uses dimension stock thicker than 2 inches is quite often employed, and the suitability of western hemlock for such purposes should be judged by the discussion and comparisons that are made under the heading "Structural Material." Where buildings are subjected to high humidity or damp conditions, such as in some textile mills, or where the framing is subject to alternate wetting and drying, only the heartwood of decay-resistant species of wood or wood that has received a good preservative treatment should be used.

PLANKING

Only a small percentage of western hemlock dimension stock goes into planking. This is probably due to the general impression that a wood suitable for planking should be hard and resistant to decay. Observation of planking in service, however, indicates that some soft woods withstand heavy mechanical wear as well as or better than harder woods. Moreover, resistance to decay is usually not the most important factor under conditions of heavy wear, because the planking fails mechanically before it is seriously affected by decay. Under "Factory and Platform Flooring," a more detailed discussion is given of the suitability of western hemlock planking for bridge flooring, loading platforms, and other uses where it is subjected to hard wear.

RAFTERS

The requirements for rafters are very similar to those for joists and studs except that bending strength is more important and stiffness less important in case of the rafters. Rafters generally have no plaster under them so that they can safely deflect more than joists. On the other hand, they are usually lower in height than joists and must carry the load imposed by the roofing material, which, in some materials, such as slate, may be considerable. In addition, they should also be able to carry any snow, wind, or other loads that may come on them.

Good nail-holding power is desired to hold roofing boards in place; uniform texture and softness to make shaping and nailing easy; and lightness and absence of warped or twisted pieces to facilitate handling and framing. Although western hemlock lacks the bending strength and stiffness of some of the species of wood shown in Figures 11 and 15, it is lighter in weight for its strength, easier to cut and frame, and less likely to deflect nails and cause them to run out the wood at the sides of the rafters than these stronger and stiffer species of wood.

Western hemlock ranks well with other species of wood commonly used for rafters. Choice of a wood for this use depends upon the type of construction and the special requirements of the individual job—whether emphasis needs to be put on maximum bending strength, stiffness, or ease of putting into place.

STRUCTURAL TIMBERS

Structural timbers go into a rather small number of uses. Engineers and architects are the consumers principally interested in this item, although some users often desire a general comparison of the strength of western hemlock beams, stringers, posts, joists, and planks with those of other species of wood. Such a comparison can be made from Table 1, which presents the recommended safe fiber stresses (a measure of the safe load-carrying capacity) for western hemlock and other species of wood commonly used for structural purposes. The safe working stresses in bending for western hemlock beams, stringers, joists, and planks are about seven-eighths of those recommended for the best of the softwoods of comparable grades, and about the same or higher than those recommended for a number of the softwoods commonly used as joists or plank, or occasionally used as stringers or as large-sized (6 by 6 inches or larger) structural timbers. The comparisons of fiber stresses (fig. 4) are for grades which meet the basic provisions of the American lumber standards. Consequently they can not be applied generally to all commercial grades even of the same name, for many of the commercial grades of structural material have not yet been revised to meet such provisions. Although Table 1 and Figures 4, 5, 6, 7, and 8 can be used for a comparison of western hemlock with other species of wood as a structural material, they are intended principally for use in design. Since the determination of which of the properties listed on the foregoing table and figures should control the design in an individual case is a highly technical problem, its solution should usually be left to an engineer or architect.

Little or no western hemlock at present goes into structural timbers. This is because western hemlock has to compete with Douglas fir, a stronger and more decay resistant species of wood, which in the same size and grade is superior for structural purposes. In most of the building codes of the United States a single stress has been assigned to hemlock regardless of whether it is of the eastern or the western species, and these stresses, because of old prejudices, are too low for either of the hemlocks. In some codes they are only about one-half that recommended by the Forest Products Laboratory for eastern hemlock conforming to the basic provisions of the American lumber standards common grade (Table 1.) Such stresses have in the past practically barred western hemlock from the structural field. The building codes of many cities, however, are being revised, and in these revisions stresses are usually being assigned to western hemlock that give it a chance to enter the structural field.

The fact that there are at present no structural grades for western hemlock should not prevent its use for structural purposes since most structural material is cut on special orders. If the stresses recommended in this bulletin are to be used, special orders for structural timbers of western hemlock should specify that the stock meet the defect limitations of the American lumber standards or the Douglas fir structural-stringer grade.

INTERIOR TRIM

Finish, casing, base, ceiling, partition, and moulding are all discussed under interior trim, because of the similarity of the requirements for these items. Assuming the wood is well seasoned and ready for use, the important property requirements common to all of these items are freedom from warping, marring, and tendency to open at the joints; ease of working; resistance to splitting in nailing; and capacity to take and hold paint.

The outstanding characteristics of western hemlock in interior trim are capacity to take and hold paint, especially over the small knots, which are the only kind permitted in these items, and the absence of any gums or resins, which could exude in service and spoil the finish or otherwise render the material unsuitable for use. Even texture, good painting characteristics, and uniform light color recommend western hemlock for light enamel finishes. For natural finishes, where the figure and grain are often the basis for selection, the choice between western hemlock and other softwoods is a matter of personal preference. The figure in western hemlock is about as pronounced as that in the true firs, is more pronounced than in the white pines, and much less pronounced than in western larch, Douglas fir, or southern yellow pine.

EXTERIOR TRIM

GENERAL

Practically all exterior trim is painted, and good painting characteristics are therefore an important requirement. Warping either before or after the trim is put in place is objectionable since it not only detracts from the appearance but also affects the tightness of the structure. Lightness and ease of cutting and sawing are desirable, inasmuch as they facilitate construction. Most exterior trim is used where conditions are unfavorable for the growth of wood-destroying fungi. Decay resistance in exterior trim is therefore of importance only in a few specific items. Such items should be pointed out by the architect and a decay resistant species specified.

Western hemlock meets the requirements for exterior trim more like the softer and lighter woods than like the heavier and harder ones commonly used for this purpose.

SIDING

Siding is used largely for exterior covering and is ordinarily exposed to the weather. Primarily it is used to insulate or seal buildings against the weather, and secondarily to finish or improve their appearance. In standard construction, siding adds little to the strength or stiffness, and seldom fails from mechanical wear or decay. The use requires that the siding lie flat, that it shall not warp or bulge, that it nail without splitting, take and hold paint well, and maintain a good appearance. In addition, it should be light in weight and cut and saw easily. The relative importance of these properties varies with the type of building, and the order of their importance is not known.

Where siding comes in contact with the ground or is kept wet or damp by leaky eaves, or where the type of construction permits moisture to collect in the joints, the more decay resistant species of wood are preferable to western hemlock, provided they contain little or no sapwood.

Western hemlock is manufactured in drop, rustic, bungalow or colonial, and bevel siding. The grades for drop and rustic siding are identical with those for Douglas fir, but in both bungalow and bevel siding western hemlock has its own grades, which, although they have the same names as the Douglas fir grades, have more restrictive defect limitations. In addition to having stricter grade specifications, western hemlock generally runs higher in the grade than Douglas fir.

COLUMNS

Resistance to decay, while not often an important factor in exterior finish, is, however, quite often a factor in columns. Columns, even of the most durable species, will seldom last the life of the building if the construction is not carefully designed to prevent the collection of moisture around the bottoms. Proper design or preservative treatment will permit the use of western hemlock for columns, but the designs commonly used in construction are such that a more durable species is preferable providing sapwood is eliminated.

DOOR AND WINDOW FRAMES

Western hemlock is used for door and window frames to some extent although not in large quantities. Durability is not usually an important factor in frames, and western hemlock can be used with satisfaction. On the other hand, under conditions favorable to decay, western hemlock should not be used without preservative treatment.

FLOORING

Western hemlock has a combination of properties which make it useable in many types of flooring. Its light, clear color and good finishing qualities are responsible for its use in flooring where good appearance under moderate wear is the most important requirement. It withstands heavy service of either abrasive or impact type. On the other hand, it mars and dents more easily than the hardwoods and softwoods commonly used for flooring, and is not suitable for use where decay resistance is of first importance.

A considerable portion of the clear western hemlock stock is manufactured into flooring 3, 4, and 6 inches in width and 1, 1¼, and 1½ inches in thickness. The grades are identical with those for Douglas fir. The A grade comes in vertical grain only, B and C grades in either flat or vertical grain, and D in only mixed flat and vertical grain. A few mills specialize in the manufacture of narrow (2⅜-inch finished face width) vertical-grained end-matched western hemlock flooring.

RESIDENCE, OFFICE, AND BALLROOM

Residence, office, ballroom, and similar floors are subject to denting or marring under rolling loads imposed by bookcases, pianos, or other articles of furniture or equipment, and to slight abrasive wear from shoes comparatively free from cutting grit. They are also likely to cup or open at the joints after being laid as a result of shrinkage with changes in moisture content. Such floors are usually protected from abrasive wear by varnish, shellac, or similar coatings. The bending strength and decay resistance of the flooring are of importance only in exceptional cases, for with standard construction the floor has a margin of safety so high that rupture seldom or never occurs, and the conditions are normally unfavorable for fungous action.

Hardwoods are more generally used for such floors than western hemlock and other softwoods because of their greater hardness, because of their appearance, and because they will wear less where the finish is not maintained. Western hemlock is somewhat easier to lay than the woods commonly used for flooring, since it is less subject to warping, easier to cut and nail, and less likely to split in nailing. Experience with western hemlock as a high-grade finish floor, however, has been confined largely to its use as an alternate for hardwoods in bedrooms on the Pacific coast and for gymnasium and armory drill floors.

PUBLIC BUILDINGS

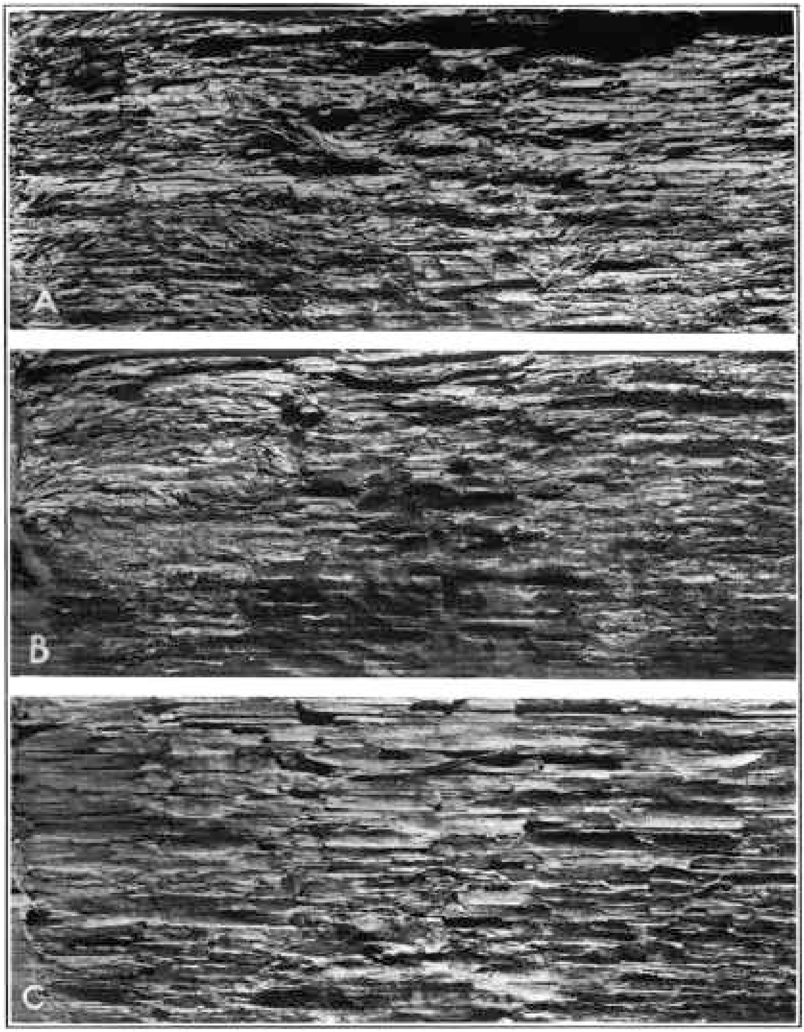
Floors in which the wood is practically unprotected and also subjected to heavy abrasive wear from shoes aided by sand, grit, and other cutting materials are found in stores, schoolhouses, auditoriums, and other public buildings. The properties desired for such floors are hardness, freedom from a tendency to sliver, and small tendency toward cupping. Resistance to decay is also occasionally desirable, but nondurable wood can be used satisfactorily if provision is made to protect the floor in the vicinity of drinking fountains, taps, and other sources of excessive moisture. Appearance is usually given little consideration because it is impractical to maintain polished or highly finished surfaces on this type of floor.

Generally in floors of this type the hardwoods will give better service than western hemlock. Western hemlock, however, is softer, easier to cut, and less likely to split in nailing and therefore easier to lay. A comparison of the hardness, texture, and ability to stay in place of western hemlock and the softwoods commonly used for flooring is made in the tables, figures, and text under "Mechanical and Physical Properties."

PORCH

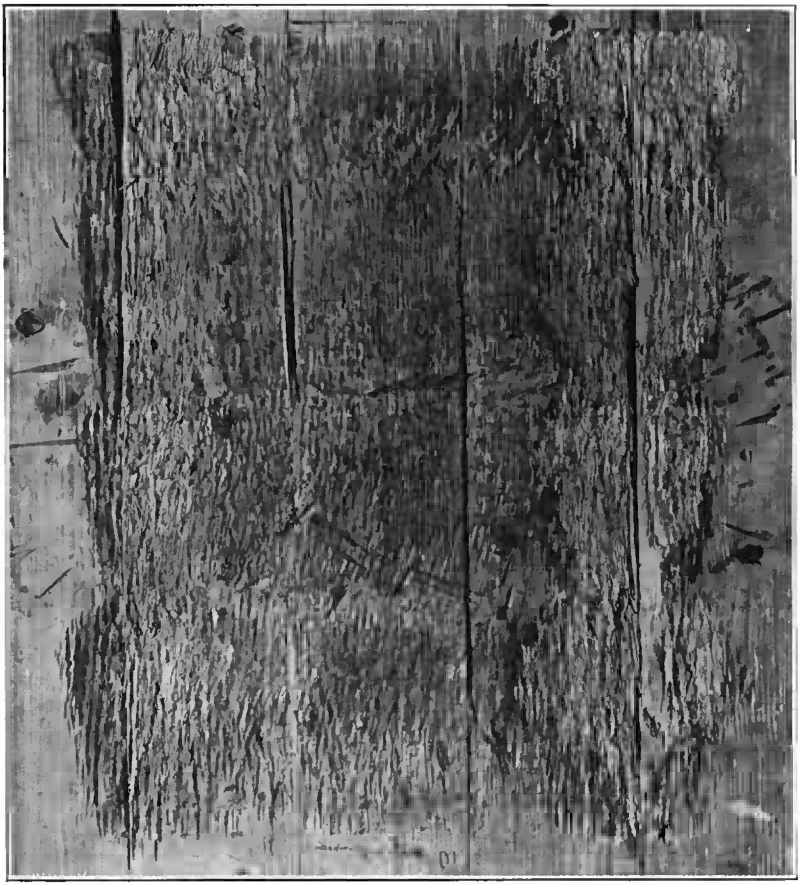
Porch flooring is representative of a type that is subjected to moderate wear and to conditions more or less subject to decay. Good painting characteristics are desirable, because practically all such flooring is painted. The wearing surface is wet from time to time either from scrubbing or from rain, a condition likely to cause cupping.

Western hemlock has a more uniform texture, less tendency to cup, and takes and holds paint better when it is applied by present standard methods than many of the species now used. Western hemlock, therefore, compares favorably with them for floors where wetting is infrequent and drying is rapid. Highly decay resistant species of wood or species that have received a preservative treatment are necessary where wetting is sufficiently thorough and frequent to be conducive to decay action.



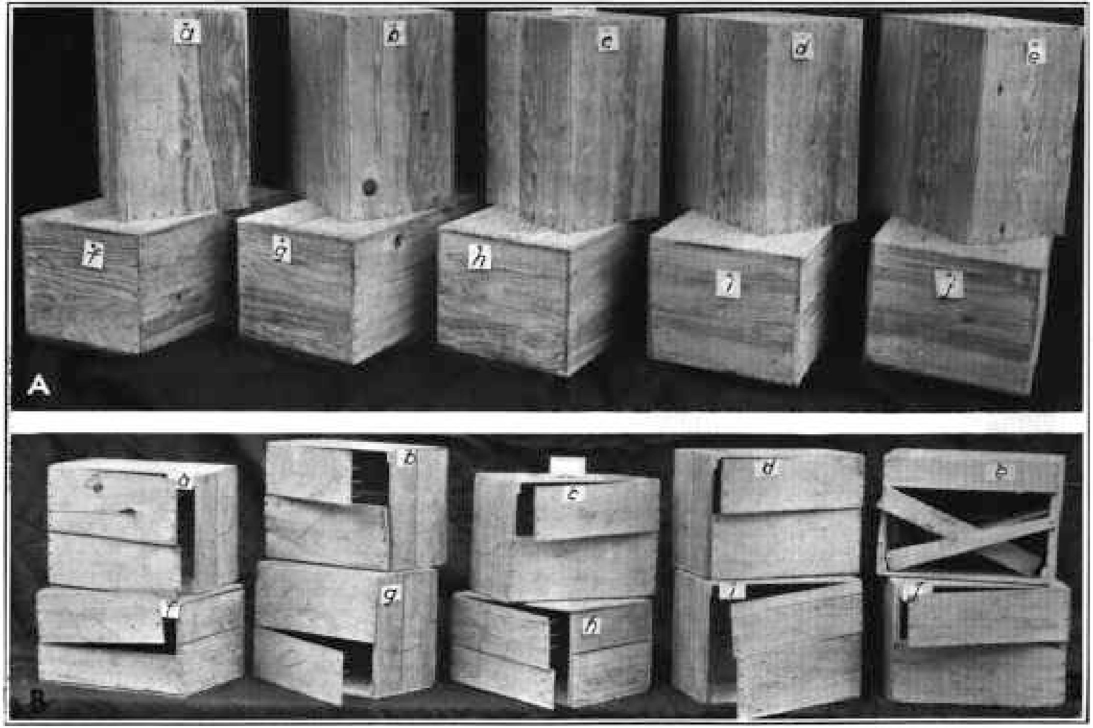
RESULTS OF HEAVY SERVICE TESTS ON PLANKING OF WESTERN HEMLOCK AND OTHER SPECIES OF WOOD

A.—"Toothpick" splintering common in hard softwoods.
B.—Matted fibers in western hemlock.
C.—Scaly type of failure common in very soft softwoods.



RESULTS OF HEAVY SERVICE TESTS ON WESTERN HEMLOCK PLANKING

Service conditions reproduced with cleated machinery wheels. Impact came immediately adjacent to the inner edges of the two outside planks. The center plank received rolling loads only. The 2-inch planks are cut about one-half through at impact points. Center plank is only marred and crushed on surface. Fibers are matted rather than scaled or splintered.



WESTERN HEMLOCK BOXES BEFORE AND AFTER BEING TESTED TO DESTRUCTION

A.—Standard canned food boxes ready for testing. Boxes are light colored, bright and neat in appearance, and are high in strength for their weight.
B.—Canned food boxes after test. The splitting shown in edges of the box ends is the result of the racking boxes received in testing.

FACTORY AND PLATFORM

In factory and warehouse floors and in planking used for bridge flooring, loading platforms, and railroad crossings, the wood is subjected to cutting and gouging from the caulked shoes of horses, to shocks from dropped boxes and castings, to impact from heavy autotrucks or other moving loads, and to abrasion from wheels rolling over sand, grit, or filings. In this type of flooring, the mechanical wear is generally so rapid that it is the principal cause of replacements even where conditions are favorable for decay. For example, untreated railroad-crossing planking, practically sound, is often removed after one or two years because of mechanical failure. Resistance to decay, therefore, may or may not be important, depending upon the severity of wear. Wood for flooring subjected to heavy service should be sufficiently hard to withstand the crushing action of wheels, should wear evenly under abrasion, and should not splinter excessively—that is, it should not open up between annual rings or peel in large pieces or slivers. Such slivers are not only objectionable because they represent a loss of wearing surface, but they are dangerous to foot traffic and leave holes or rough spot around which wear is increased from the bumping and jarring of moving loads.

Western hemlock is fairly uniform in texture. The spring wood and summer wood merge without decided contrast, as shown in Plate 8, A. The result is an even-wearing surface which develops no high ridges of summer wood. Western hemlock under heavy wear is reported to mat rather than to splinter or scale. The "toothpick" type of splintering (pl. 9, A), is representative of the hard softwoods; the scaly type of splintering (pl. 9, C), of the soft softwoods; and the intermediate type (pl. 9, B), of western hemlock. The specimens shown in Plate 9 were cut from panels that had been subjected to the impact and rolling action of a set of heavy, cleated machinery wheels. The full western hemlock panel used in this test is shown in Plate 10. The impact wear adjoined the inner edge of the two outside planks. Here the planks are gouged about half way through the thickness, while the center plank, which was subjected to rolling action, is practically intact except for marring or crushing. The severity of wear under impact indicates the necessity of maintaining a smooth surface in view of the fact that large slivers, badly worn spots, and large knots increase impact wear by increasing the bumping and jolting action.

Heavy flooring of western hemlock will withstand the crushing action of smooth rolling loads better than softer species of wood, but not so well as the harder species. Individual western hemlock planks wear more evenly and smoothly than planks with pronounced alternate bands of hard and soft wood, and thereby reduce the injurious effect of impact loads. Where wear is light such as that from light rolling rather than heavy impact loads, and where conditions are favorable for decay, the heartwood of decay-resistant species of wood should be used in preference to untreated western hemlock. Pacific coast manufacturers of lumber have long used western hemlock and other local species of wood for floors of buildings in lumber camps, for wharf planking, and in other places about lumber yards and mills where the traffic is heavy. In such floors western hemlock has worn evenly and fuzzed rather than splintered. However, comparatively little western hemlock has been used for heavy-service flooring and planking in spite of the fact that the available information indicates that it is suitable for such purposes.

INDUSTRIAL USES

Western hemlock has been and is employed for hundreds of specific industrial uses. It is impracticable to discuss all of the specific uses not only because of the large number involved, many of which consume only a relatively small amount of material, but because the essential requirements of many of the uses are not known. The uses selected for discussion are those that consume the largest quantities of western hemlock, those that are important because their requirements are such that western hemlock may eventually furnish a substantial part of their requirements, or those that appear to offer a special market for western hemlock. The discussion consists of a correlation of the requirements of use with the properties of western hemlock. Even in specific uses the relative importance of the properties is not fully known, and, as in the previous discussion of use items, the requirements of use as presented are the result of observation and experience rather than of scientific laboratory or service tests.

SHIPPING CONTAINERS

More lumber goes into shipping containers than into any other single industrial use. About 10½ per cent of the total lumber cut and 9½ per cent of the total softwood cut in 1925 went into boxes and crates. Two hundred and ninety-six million board feet, or about one-fourth of all the western hemlock cut in 1926, went into boxes and crates, furnishing about 8½ per cent of all the softwood lumber used for this purpose. The species is used for all but a few specialized types of containers.

The properties desired in general for containers are lightness combined with comparatively high shock resistance, low tendency to split in nailing, high splitting resistance, high nail-holding capacity, light color in order to take and show any markings well, and, for some types, absence of odor and taste. In addition, a species of wood to be extensively used for containers must be available in large quantities and in grades that are comparatively low in price.

Western hemlock stands third in availability as to stand and fifth as to cut, it is light colored, imparts no odor or taste to the contents, and has a high shock resistance for its weight. (Table 2.) Its nail-holding capacity and splitting resistance, as compared with other species of wood, are shown in Figures 18 and 20, respectively. Its hardness (fig. 13), combined with its splitting resistance (fig. 20), indicates its tendency to split in nailing. Of the two properties hardness is the more important.

A series of tests in a box-testing machine (*17*) was recently made on standard canned-food boxes of a number of species of wood, including western hemlock, at the Forest Products Laboratory. One series of boxes was nailed and tested while in the green condition, one series was nailed while the wood was in the green condition and tested after drying in storage, and another was nailed while in an air-dry condition and tested immediately. Plate 11, A, shows some of the western hemlock boxes before test and illustrates the type of box used in the test. The results of the test indicate that the nailing is more important than the species of wood used. Boxes made of western yellow pine, a species lower than western hemlock in most strength properties, withstood as much rough handling as those of western hemlock. This is accounted for by the fact that western hemlock splits more. Plate 11, B, shows the splitting, which is due largely to the racking the boxes received in testing, that developed in the edges of the western hemlock box ends during test. Seven of the ten boxes illustrated show failure from splitting. Boxes *a* to *e* were nailed with six-penny nails, while boxes *f* to *j* were nailed with five-penny nails. Boxes nailed with six-penny nails gave the best results.

The tests demonstrated that although boxes of any species of wood nailed while in a wet or green condition lose strength in drying, the loss in strength of western hemlock boxes is especially high. Boxes made of green western hemlock and tested after drying in storage withstood only about one-twentieth of the rough handling withstood by air-dried hemlock boxes, and the loss in strength was more pronounced in the boxes of hemlock than in any of the other species of wood tested. The present practice of drying all western hemlock box lumber is, therefore, a good one, and is largely responsible for the success that western hemlock has had as a box lumber.

FOOD CONTAINERS

Highly resinous woods can not compete with western hemlock and other nonresinous softwoods for use as containers for food products, which may be injured by an odor or flavor imparted by the wood of the container.

In addition to the reported experience of a number of users that western hemlock in no way injured their product, tests made by the Bureau of Animal Industry [13] indicate that "western hemlock may be used for butter containers without imparting sufficient woody flavor to the butter to be commercially objectionable." The large quantities of western hemlock readily available and the growing demand for other purposes for the species now widely used as food containers will tend to bring about the increasing use of western hemlock for this purpose.

COOPERAGE

Containers classed as cooperage are kegs, kits, tierces, barrels, tubs, pails, and buckets. Some of the properties desired for such articles are those common to practically all containers. Nailing and splitting characteristics, however, are much less important in cooperage, and ability to stay in place more important. In addition, tight cooperage must be easily bent to shape and must hold liquids.

The desirable properties of western hemlock for cooperage are its slight tendency to impart odor, taste, or color once it has been dried, the ease with which it can be worked, its ability to stay in place, and

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[13] UNITED STATES DEPARTMENT OF AGRICULTURE, BUREAU OF ANIMAL INDUSTRY. Op. cit.

its moderate shrinkage. No information is available upon the ease with which it can be bent for cooperage. It is used largely for small pails and tubs and nonliquid containers.

FREIGHT-CAR CONSTRUCTION

Under this heading are a number of items, such as siding, roofing, running boards, framing, and decking. The general requirements for roofing and running boards are much the same as those described under siding. The requirements for framing are similar to those described for joists and studs, and those for decking are similar to those described under factory and platform flooring. Car material, however, is subject to severer conditions than construction material, and the relative importance of some of the properties change. A car may pass in a short time from the Northwestern States, where the relative humidity is high and the temperature moderate, tending to bring the wood to about 20 per cent moisture content, to the Southwestern States, where the temperature is high and the relative humidity very low, tending to bring wood to a moisture content of about 6 per cent. Buckling and shrinkage of car material are common results from these varying moisture conditions. Shrinkage and ability to stay in place, therefore, are important requirements in car material.

Resistance to decay is also more important in car material than in house construction. Freight-car manufacturers, when interviewed in the course of a general survey, have stated that the failure of wood in freight cars is quite generally caused by decay. The heartwood of almost all the softwood species commonly used for car material is more resistant to decay than is that of western hemlock. On the other hand, western hemlock holds paint better, stays in place as well as, and nails with less splitting than Douglas fir and southern pine, which in 1925 constituted 97 per cent of the softwoods used for this purpose. These two species of wood, however, have higher strength values than western hemlock and will withstand more rough usage.

The production of car siding from western hemlock is increasing. A large number of mills produce this item, and a few convert their entire cut of select hemlock into it. The demand for western hemlock for car siding is due to several factors, including its good painting characteristics, absence of grain rising and resin, its lightness, and the fact that decay resistance is not so important in siding as in other car material.

Running boards, since good footing is very desirable, require a wood that wears evenly under abrasion, does not develop loose splinters, and has a small tendency to warp under exposure to weather. Decay resistance is also desirable since the boards are exposed to alternate wetting and drying. A comparison in texture, hardness, ability to stay in place, and resistance to decay of western hemlock and other species of wood will furnish a good basis upon which to judge its suitability for running boards.

While western hemlock is extensively used for framing in buildings, very little if any is used for car framing. Species of wood with higher strength properties, especially in shock resistance, bending, and compressive strength (figs. 11, 12, and 14), are generally chosen. Western hemlock to be a successful alternate for stronger species should be of a higher strength grade or of larger size.

Car decking at intervals is subjected to heavy wear, is not protected with any finish, and in some cases, as in stock cars, is subject to conditions very favorable for decay. For such a use, uniform wear is desirable and slivering is objectionable, but marring or denting is not objectionable. Only a small quantity of western hemlock is used for car decking, the principal softwoods used being Douglas fir and southern pine. Western hemlock splinters less and should wear more uniformly than these species, but it is softer and has lower strength properties. Plate 10 shows the characteristic wearing failures of western hemlock and those of harder and softer woods. Western hemlock, however, should not be used for decking in stock cars without preservative treatment.

LADDERS

Ladders consume only a small part of the total lumber cut, a fraction of 1 per cent, but this use is discussed because western hemlock is at present entering the ladder market as an alternate for species of wood long used for this purpose. The consumer traditionally prefers a light-colored ladder wood; for this reason color influences the choice of species of wood for ladders as much as if not more than such properties as weight (fig. 9), shock resistance (fig. 14), strength in bending and compression endwise (figs. 11 and 12), straightness of grain, and absence of tendency to sliver. Comparison of these properties of western hemlock with those of species of wood commonly used for ladders may be made from figures of the text under "Mechanical and Physical Properties." Such a comparison of western hemlock with the principal species of wood used for ladders shows that it is somewhat heavier, slightly lower in shock resistance, and slightly higher in bending and endwise compressive strength than these species.

Ladder manufacturers report difficulty in obtaining species of wood long used for ladders as a result of the demand for similar stock in other uses. On the other hand, western hemlock, which will meet the ladder-stock specifications, is still relatively easy to obtain.

FURNITURE

The value of western hemlock as a furniture wood is due to its freedom from resin, ease of working, combination of weight and strength, ability to stay in place, and painting and gluing characteristics rather than to its beauty or ability to take highly polished finishes. It is, therefore, used principally in furniture where service is more important than appearance.

Kitchen, drop-leaf, breakfast, and Windsor tables, desks, washstands, and cots are the principal articles of furniture in which western hemlock is used throughout. The use of western hemlock for such articles, however, has been retarded by the marketing of insufficiently or improperly dried lumber. Some manufacturers also object to the "dark streak" of western hemlock, but the dark streak is not a serious or particularly undesirable defect in painted articles.

Western hemlock is used in high-grade furniture principally for the backs of dressers and bureaus, bottoms of drawers, frames of kitchen cabinets, overstuffed chairs, and davenports, and interior framing of refrigerators.

CORE STOCK FOR VENEER PANELS

It is estimated that 350,000,000 board feet of lumber is used annually for core stock. Consumption of wood for this purpose has been increasing rapidly and will probably continue to increase because of the demand for veneered furniture and other products. Only a very small amount of western hemlock is used for cores. Chestnut has been one of the principal core woods, but on account of the destruction caused by the chestnut blight this wood will not be available in the desired quantities indefinitely. Veneer-panel manufacturers have for some time, therefore, been looking for suitable alternate woods which have the desired properties and which are available in large quantities. Ability to stay in place, small and uniform shrinkage, uniform texture, ease of gluing, ease of working, and lightness are the more important of the properties desired.

In gluing properties western hemlock compares favorably with most of the woods now used for core stock. In ability to stay in place, workability, and lightness it occupies an intermediate position as compared to the species of wood now commonly used for cores, and is available in larger quanties than any of the principal core woods.

Grain rising with the resulting irregularities and grain markings showing through thin face veneers are the principal objections to softwood species with pronounced bands of hard and soft wood. In this respect western hemlock should not prove objectionable. Edge-grained material will, of course, give better results than flat-grained, both because the markings are not so pronounced and the shrinkage in width is roughly only about about one-half as large.

Experience indicates that western hemlock is a suitable wood for cores, and should be considered when the selection of a new species of wood is desirable. In edge-grained form it is used by some manufacturers for cores in high-grade veneer panels for desk tops; these panels, like other high-grade ones, are cross-banded.

VENEER

The properties of importance in veneer are ease of gluing, ability to take finish, ability to stay in place, ease of working, and for some uses shock resistance or toughness. In addition, the size of the trees and the percentage of clear material obtainable from them are of importance in determining the suitability of a species of wood for the manufacture of veneer, since these factors determine the percentage of waste and the quality of the veneer obtainable. This is especially true with the rotary process of cutting veneer, which is commonly used in the Northwestern States. Western hemlock has a favorable combination of the properties desired in the manufacture of veneer. Western hemlock logs, however, are on on average smaller and produce a smaller percentage of high-quality veneer than the species associated with it in the forest, and as a result the species is not extensively used.

Western hemlock veneer finds its principal use in the production of fruit and vegetable containers. A comparison in toughness of western hemlock and other species of wood (fig. 14) indicates the relative breakage to be expected when thin veneer must be bent or crimped in the manufacture of containers. The tougher the species the less the breakage. Toughness is also desired in the thick veneers, such as are used for slats, sides, and tops of crates and boxes.

POLES

The most important properties for poles are resistance to decay, strength in bending, and lightness. In the selection of softwood species for poles, the combination of lightness and resistance to decay has in the past been considered to the exclusion of practically all other properties. In the last few years, however, owing to improvements in preservative treatments, species of wood of high strength but of low decay resistance have entered the pole market in considerable quantities.

Western hemlock is practically unknown in the pole field, having never been used for this purpose except in short, more or less temporary, lines erected close to where western hemlock grows. The principal reason why western hemlock is not used is the availability in the same markets of more decay-resistant and lighter though weaker species of wood. Even the trend toward the use of treated poles does not promise to open a large market for western hemlock, (*35*), because it will also open the market to a number of other species of wood of which there are large, available pole stands.

PILING

Decay and marine borers are the most common causes of failure in piling. Resistance to decay and resistance to marine borers are, therefore, important properties. In addition to being decay resistant, piling must have sufficient strength to stand driving and must not " broom " under the hammer. Western hemlock, not being resistant to the attack of marine borers or fungi, is unsuited for piling unless given a preservative treatment or unless used where conditions are unfavorable to fungous or prohibitive to borer attack, as in wood completely submerged in fresh water. The bark of western hemlock appears to be resistant to the attack of marine borers (teredoes) and wood lice (limnoria) (*5*). Even though the western-hemlock bark appears resistant to the attack of marine borers, the use of untreated hemlock can not be recommended because of the practical certainty of pieces of bark being broken off at knots or in handling or driving, thus exposing the wood.

Western hemlock is used for piling in Alaska, but, except in that locality, very little of the species goes into this use. The growth characteristics of the species are such that a large amount of long, straight, high-grade piling can be obtained from it, and with the increased use of preservatives more hemlock piling may be used.

PULP AND PAPER

Three genera of wood—the spruces, firs, and hemlocks—supply about three-fourths of the wood consumed in the United States for the manufacture of pulp and paper (*32*).

Western hemlock pulp produced by the sulphite process is of a quality suitable for use, unbleached, in newsprint paper. It can be bleached for use in higher grade products, such as bond, writing, and ledger papers. As compared with the spruces, western-hemlock sulphite pulp hydrates more readily, is darker in color, and is bleached with more difficulty. In sulphate or kraft pulps, where strength is desirable but the color of the product is relatively unimportant, western hemlock is practically as good as the spruces or the firs which are commonly used for this purpose. Kraft pulps are used in wrapping papers, container boards, and similar products, and are seldom bleached.

Ground-wood pulp is produced by grinding wood on a grindstone. It makes a paper that is inferior in strength and durability to that obtained from the chemical pulps, and consequently is used in admixture with chemical pulps, usually sulphite, in the manufacture of papers where permanency is not required, such as newsprint, cheap catalogue, and magazine papers. Ground wood requires the use of a large amount of power, but the pulp yield is high, being 90 per cent or more of the original weight of the wood. Western hemlock, because of its hardness, requires a larger amount of power in grinding than the firs or the spruces. In addition, western hemlock produces a darker-colored pulp. Consequently, the firs and spruces are preferred to western hemlock for grinding purposes.

On the basis of the amount of wood consumed, western hemlock is the leading pulp wood of the Western States (*12*, *14*). The greatest demand is for newsprint paper, and 76 per cent of this item manufactured on the Pacific coast is made from western hemlock. Western hemlock is practically the only wood used on the Pacific coast for the manufacture of sulphite pulp.

RAILWAY CROSSTIES

A combination of such properties as hardness (fig. 12), shock-resisting ability (fig. 14), and capacity to take preservatives largely determines the choice of a species for crossties. However, resistance to the withdrawal of spikes, and resistance to splitting, checking, and twisting are also important factors. Decay resistance is only important when crossties are used untreated. About three-fourths of the ties purchased in 1927 were treated with preservatives. The proportion of treated ties is increasing, tending to lessen the importance of resistance to decay of untreated wood and to increase the importance of the effectiveness of preservative treatment.

The life of treated and untreated crossties of different species of wood in different localities varies so widely in individual cases that figures representing the average length of service are of little value. For example, the estimated average life in the Northwestern States of untreated western hemlock ties in tracks subjected to heavy traffic is five to six years. On the other hand, the Government railroads in Alaska, which use western hemlock almost exclusively for crossties, report an average life of from 9 to 10 years for untreated western hemlock. This is almost double the estimated life of western hemlock ties in the United States, and illustrates the wide variations to be expected in different localities.

Of the 3,500,000 eastern and western hemlock ties reported in the 1925 census, eastern hemlock furnished by far the larger proportion. The bulk of western hemlock ties are used in the vicinity of their growth for logging railroad tracks.

MINE TIMBERS

The requirements for mine timbers, although such timbers are used for structural purposes, differ somewhat from the property requirements described for structural timbers in that decay resistance becomes more important. Shock resistance also becomes important, since species of wood with high shock resistance furnish warnings of failure. Strength in bending and compression (endwise), however, are by far the most important strength properties (*16*). The selection of mine timbers differs widely from the selection of structural timbers. Structural timbers are usually selected and graded for strength, while sawed mine timbers are ungraded. The sawed Douglas fir and southern yellow pine mine timbers now commonly used consist of boxed-heart, wide-ringed, low-density material whose strength will run below the average for the species. They represent what is left after the better and more valuable material has been cut from the log. On the other hand, mine timbers of western hemlock and some of the other moderately strong species of wood are sometimes log run and are therefore fairly representative of the average strength of the species, and may be even above average in strength. As a result mine timbers of western hemlock are usually nearer equal in strength to those of Douglas fir and southern yellow pine than the average strength figures (figs. 11 and 12) indicate. In the purchase of sawed mine timbers, therefore, more consideration should be given to grade or quality than to the average strength of the species. Likewise sawed mine timbers of Douglas fir and southern yellow pine are likely to contain little sapwood and are more decay resistant than those of western hemlock, which fact should be considered where the timbers are to be used under conditions favorable for decay.

Round timbers are often selected without regard to grade or species because of their availability. Where both Douglas fir and western hemlock round timbers are available, as is generally the case, the Douglas fir is preferred because of its higher strength and decay resistance.

Untreated western hemlock makes a good mine timber for use where the working is dry or where the life of the working is less than the life of hemlock timbers. In permanent mine work, where conditions are favorable for decay, western hemlock if used should be treated. The selection of round timbers for permanent mine work should be based on the quality or strength of the run of timber rather than upon the species.

LATH

Plasterers generally demand green lath and lath of a species of wood that stays in place well. Lathers want a wood that does not split readily when nailed and that is soft enough to cut easily with a single blow of the hatchet. Builders generally prefer a light-colored lath, clean, and comparatively free from stain. The demand for green lath confines the use of western hemlock primarily to States along the Atlantic and Pacific coasts. Western hemlock stays in place well, does not split readily when nailed, is moderately soft, light colored, and generally free from stain. The principal objection to hemlock lath in the past has arisen from the staining of the plaster by the bark. Pieces containing bark were never very common in western hemlock lath and are now excluded by the grading rules, which were revised to eliminate this objection to the species. About one-third of the lath produced in the United States is now cut in Oregon and Washington, perhaps 10 per cent of their production being western hemlock.

FUEL

Very little western hemlock is used for fuel (*27*) although there are thousands of cords available from the waste which occurs in the manufacture of lumber and in logging. There appears to be no early prospect of this waste material being utilized for fuel because in the localities in which it occurs there is an abundance of waste of other species of wood that are preferred because of their greater fuel value per cord. The marketing of wood waste for fuel at a distance from the locality where it is grown is not profitable because of the higher heating value of coal, both per unit of weight and per unit of volume, which makes coal cheaper to transport, handle, and much more convenient to use.

TANNIN

Very little western hemlock bark is used for tanning purposes in spite of its high tannin content. The several tanneries of the west coast generally use quebracho from South America and native tanbark oak bark. Under present conditions western hemlock bark apparently can not compete with these materials. Neither can it at present compete with eastern hemlock bark, quebracho, etc., in the eastern tanning markets.

EXCELSIOR

The properties required in wood for manufacturing excelsior are ease of working, straightness of grain, uniformity of texture, and the absence of dense, hard streaks, or knots. Excelsior of high quality must be tough, resilient, light in color, and without odor, taste, resin, or gum. There appears to be some unknown quality or qualities in wood, probably of texture or structure, which accounts for the fact that the higher quality products are obtained from other than the tougher and stiffer species of wood.

While western hemlock combines a number of the properties desired for wood suitable for excelsior, it has some characteristics which make its use doubtful. Excelsior manufacturers state that strands of western hemlock will not curl up satisfactorily and will break in baling. The tendency to break rather than curl is exhibited by western hemlock shavings from planers and other woodworking machinery. Manufacturers also believe that the black knots of western hemlock would cause excessive breakage in spurs of excelsior-manufacturing machines. In view of the above objections and in the absence of data, an extensive trial or test should be made before attempting to manufacture excelsior from western hemlock on a commercial scale.

REPORTED MISCELLANEOUS USES FOR WESTERN HEMLOCK

There are a large number of miscellaneous uses into which western hemlock now goes that are not discussed because of the small quantity of material they consume, because of lack of knowledge as to their required properties, or because their requirements are enough like some uses already discussed for the comparisons and analyses to apply in part or with slight changes.

The following is a partial list of miscellaneous uses for western hemlock which has been compiled from observations of members of the Forest Service and from a survey of trade literature. While the list may be useful as a reference for possible uses for western hemlock, it should be remembered that the fact that a species of wood has been used for a specific purpose does not indicate that it is the best wood for that purpose. In fact, a brief inspection of the list will reveal that it contains a number of uses for which other species are obviously better suited than western hemlock.

PARTIAL LIST OF USES FOR WESTERN HEMLOCK

Airplanes.
Backing, furniture.
Balls.
Balls, topmast.
Balusters.
Balusters, porch.
Baskets.
Baskets, fruit.
Bottoms.
Bottoms, drawer, furniture.
Bottoms, dredge.
Boxes.
Boxes, goods, canned.
Boxes, product, food.
Boxes, shipping, heavy.
Cabinets, kitchen.
Cases.
Cases, food.
Casing.
Casing, box, controller, electric, car.
Casing, head, house.
Caskets.
Caskets, outside boxes.
Ceiling.
Cooperage.
Cooperage, slack.
Coaches.
Crates.
Crates, vegetable.
Crating.
Doors.
Doors, screen.
Drawers.
Drawers, fixture.
Drawers, furniture.
Finish.
Finish, boat.
Finish, exterior, house.
Finish, interior.
Finish, interior, house.
Fixtures.
Flooring.
Flooring, car, freight.
Frames, couch.
Frames, well, oil.
Frames, window.
Fuel.
Furniture.
Implements, agricultural.
Joists.
Joists, floor, house.
Lath, house.
Molding.
Molding, exterior, house.
Newels.
Pails.
Panels.
Panels, house (interior trim).
Posts.
Posts, newel.
Posts, newel, angle.
Posts, newel, starting.
Products, mill, planing.
Pulp, paper.
Refrigerators.
Refrigerators and kitchen cabinets.
Roofing.
Roofing, car.
Roofing, car, freight.
Roofing, car, railroad.
Sash.
Sash, doors and blinds.
Sash, window.
Scantling.
Screens.
Screens, window.
Shelves.
Shelves, fixture.
Shelves, furniture.
Shelving.
Shooks.
Shooks, box.
Sides, drawer.
Sides, drawer, furniture.
Siding.
Siding, car, freight.
Siding, house.
Silos.
Staves.
Staves, silo.
Staves, tub, butter.
Tables, kitchen.
Tanks.
Ties, cross.
Timbers, construction, heavy.
Tops, furniture.
Tops, table, kitchen.
Veneer.
Wainscoting.
Woodenware.
Woodenware and novelties.

LITERATURE CITED

(1) ANONYMOUS.
1926. TANNIN FROM WESTERN HEMLOCK. Timberman 27 (11): 178, 180.

(2) ALLEN, E. T.
1923. FOREST FIGURES FOR THE PACIFIC COAST STATES. U. S. Senate Select Committee on Reforestation, [18] p.

(3) AMERICAN RAILWAY ENGINEERING ASSOCIATION.
1926. REPORT OF COMMITTEE VII—WOODEN BRIDGES AND TRESTLES. Bul. Amer. Ry. Engin. Assoc. 27 (284): 829–912.

(4) AMERICAN SOCIETY FOR TESTING MATERIALS.
1925. REPORT OF SUBCOMMITTEE I ON SPECIFICATIONS FOR TIMBER. 25 (Pt. 1): 312–334.

(5) ATWOOD, W. G., and JOHNSON, A. A.
1924. MARINE STRUCTURES, THEIR DETERIORATION AND PRESERVATION . . . 534 p., illus. Washington, D. C.

(6) AUSTIN, L. W., and EASTMAN, C. W.
1902. ON THE RELATION BETWEEN HEAT CONDUCTIVITY AND DENSITY IN SOME OF THE COMMON WOODS. Wis. Acad. Sci., Arts, and Letters, Trans. 13: [539]–542, illus.

(7) BENSON, H. K., THOMPSON, T. G., and WILSON, G. S.
1923. THE CHEMICAL UTILIZATION OF WOOD IN WASHINGTON. Wash. [State] Engin. Expt. Sta. Bul. 19, 160 p., illus.

(8) BROWNE, F. L.
1927. SPREADING RATE OF OUTSIDE WHITE HOUSE PAINT. Painters Mag. 54: 10–15, 83, illus.

(9) ———
1927. TECHNICAL STUDY OF WOOD PAINTING PRACTICE. Amer. Paint Jour. 5: 20–28, illus.

(10) BURKE, H. E.
1905. BLACK CHECK IN WESTERN HEMLOCK. U. S. Dept. Agr., Bur. Ent. Circ. 61, 10 p., illus.

(11) BURNS, R. M., and FREED, B. A.
1928. CORROSION OF CABLE SHEATH IN CREOSOTED WOOD CONDUIT. Jour. Amer. Inst. Elect. Engin. 67: 576–579, illus.

(12) CLAPP, E. H., and BOYCE, C. W.
1924. HOW THE UNITED STATES CAN MEET ITS PRESENT AND FUTURE PULP-WOOD REQUIREMENTS. U. S. Dept. Agr. Bul. 1241, 100 p., illus.

(13) FULLAWAY, S. V., JR., and HUBERT, E. E.
1925. AIR SEASONING OF LUMBER IN INLAND EMPIRE. Timberman 26 (5): 50–54; (6): 61–66, 144; (7): 65–66, 68, 70; (8): 56-64.

(14) GIBBONS, W. H.
1927. THE FORESTS AND THE WOOD-USING INDUSTRIES OF WASHINGTON. West Coast Lumberman 52 (614): 50–72, 75–80, 102–106; (615): 27–28, 46; (616): 24, 56–58; (617): 27–28, 49; (618): 47–51; (619): 52–54.

(15) JOHNSON, H. M., and GIBBONS, W. H.
1926–27. THE AIR SEASONING OF LUMBER IN THE DOUGLAS FIR REGION. Timberman 27 (12): 38–41; 28 (1): 38–41; (2): 40–44; (3): 38–41.

(16) JOHNSON, R. P. A.
1923. THE STRENGTH OF MINE TIMBERS. Com. Rpt. Sect. Mine Timbers, Amer. Mining Cong., 1923, pp. 24–29.

(17) NATIONAL ASSOCIATION OF BOX MANUFACTURERS.
1921. WOODEN BOX AND CRATE CONSTRUCTION. 208 p., illus. Chicago.

(18) NEWLIN, J. A.
1927. UNIT STRESSES IN TIMBER. Amer. Soc. Civ. Engin. Trans. 91: 400–407, illus.

(19) ROWLEY, F. B.
1923. TRANSMISSION OF HEAT THROUGH BUILDING MATERIALS. Minn. Univ. Engin. Expt. Sta. Bul. 3, 74 p., illus.

(20) SNYDER, T. E.
1927. PREVENTING DAMAGE BY TERMITES OR WHITE ANTS. U. S. Dept. Agr. Farmers' Bul. 1472, 22 p., illus. (Revised ed.)

(21) SOUTHERN PINE ASSOCIATION.
1927. STANDARD SPECIFICATIONS FOR GRADES OF DENSE LONG LEAF AND SHORT LEAF SOUTHERN YELLOW PINE . . . 31 p., illus. New Orleans.

(22) SUDWORTH, G. B.
1927. CHECK LIST OF THE FOREST TREES OF THE UNITED STATES, THEIR NAMES AND RANGES. U. S. Dept. Agr. Misc. Circ. 92, 295 p.

(23) THELEN, R.
1929. KILN DRYING HANDBOOK. U. S. Dept. Agr. Bul. 1136, 96 p., illus.

(24) TRUAX. T. R.
1929. THE GLUING OF WOOD. U. S. Dept. Agr. Bul. 1500, 78 p., illus.

(25) UNITED STATES DEPARTMENT OF AGRICULTURE.
[n. d.] SIGNIFICANCE OF THE "FACTOR OF SAFETY" IN WORKING STRESSES FOR STRUCTURAL TIMBERS. U. S. Forest Prod. Lab. Tech. Note 222, 3 p.

(26) ———
[n. d.] YIELDS OF ALCOHOL FROM WOOD WASTE. U. S. Forest Prod. Lab. Tech. Note 120, 2 p.

(27) UNITED STATES DEPARTMENT OF AGRICULTURE, OFFICE OF FOREST INVESTIGATIONS.
1919. THE USE OF WOOD FOR FUEL. U. S. Dept. Agr. Bul. 753, 40 p., illus.

(28) UNITED STATES DEPARTMENT OF COMMERCE, BUREAU OF STANDARDS.
1926. RECOMMENDED BUILDING CODE REQUIREMENTS FOR WORKING STRESSES IN BUILDING MATERIAL. REPORT OF BUILDING CODE COMMISSION, JUNE 1, 1926. U. S. Dept. Com., Bur. Standards Elimination of Waste Ser. BH9, 53 p., illus.

(29) ———
1926. LUMBER. U. S. Dept. Com., Bur. Standards Simplified Pract. Recommendation 16, 95 p., illus. (Revised ed.)

(30) VAN DUSEN, M. S.
1920. THE THERMAL CONDUCTIVITY OF HEAT INSULATORS. Refrig. Engin. 7: 202–231, illus. (Also published in Jour. Amer. Soc. Heating and Ventilating Engin. 26: 625–656, illus.)

(31) WEIR, J. R., and HUBERT, E. E.
1918. A STUDY OF HEART-ROT IN WESTERN HEMLOCK. U. S. Dept. Agr. Bul. 722, 37 p., illus.

(32) WELLS, S. D., and RUE, J. D.
1927. THE SUITABILITY OF AMERICAN WOODS FOR PAPER PULP. U. S. Dept. Agr. Bul. 1485, 102 p., illus.

(33) WEST COAST LUMBERMEN'S ASSOCIATION.
1926. STANDARD GRADING AND DRESSING RULES FOR DOUGLAS FIR, SITKA SPRUCE, WEST COAST HEMLOCK AND WESTERN RED CEDAR. 122 p., illus. Seattle, Wash.

(34) WILSON, T. R. C.
1921. THE EFFECT OF SPIRAL GRAIN ON THE STRENGTH OF WOOD. Jour. Forestry 19: 740–747, illus.

(35) ———
1923. RESULTS OF SOME STRENGTH TESTS ON WOODEN POLES. U. S. Forest Prod. Lab. Rpt., Ed. 2, 13 p., illus. [Unpublished.]

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